COMPARATIVE STUDY OF THE ACCURACY OF SINGLE TOOTH IMPLANTS PLACED BETW EEN STATIC AND MENTAL COMPUTER ASSISTED SURGERY

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Oral and Maxillofacial Surgery
Department of Oral and Maxillofacial Surgery
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การศึกษาเปรียบเทียบความแม่นยำของการฝังรากฟันเทียมชี่เดี่ยวระหว่างการผ่าตัดฝังรากฟันเทียม
โดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำ

น.ส.ปาลิตา สมิตกาญจน์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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ปาลิตา สมิตกาญจน์ : การศึกษาเปรียบเทียบความแม่นยำของการฝังรากฟันเทียมซี่เดี่ยวระหว่างการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำ. (COMPARATIVE STUDY OF THE ACCURACY OF SINGLE TOOTH IMPLANTS PLACED BETW EEN STATIC AND MENTAL COMPUTER ASSISTED SURGERY) อ.ที่ปรึกษาหลัก : รศ. ทพ. ดร. อาทิพันธุ์ พิมพ์ขาวขำ

วัตถุประสงค์: การศึกษานี้เป็นการทดลองทางคลินิกแบบสุ่ม มีวัตถุประสงค์เพื่อเปรียบเทียบความแม่นยำของการผ่าตัดฝังรากฟันเทียมระหว่างการผ่าตัดด้วยวิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำในบริเวณที่ฟันหายไปหนึ่งซี่

วิธีวิจัย: ผู้ป่วยที่เข้าร่วมในการวิจัยจำนวน 52 คน ได้รับการผ่าตัดฝังรากฟันเทียมทั้งหมด 60 ซี่ ถูกสุ่มเข้าสู่การผ่าตัดฝังรากฟันเทียมด้วยวิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตหรือแบบช่วยเหลือผ่านการจดจำจำนวนเท่าๆกัน ในกลุ่มการผ่าตัดฝังรากฟันเทียมด้วยวิธีคอมพิวเตอร์ช่วยเหลือแบบสถิต ข้อมูลที่ได้จากการถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ลำรังสีรูปกรวย และข้อมูลที่ได้จากการถ่ายภาพพื้นผิวในช่องปากหรือจากแบบจำลองถูกนำมาใช้ในการจำลองการวางตำแหน่งรากฟันเทียมและออกแบบแผ่นจำลองนำทางผ่าตัดในโปรแกรมที่ใช้วางแผนการผ่าตัดฝังรากฟันเทียมในลักษณะ 3 มิติ ขั้นตอนการฝังรากฟันเทียมถูกกระทำผ่านทางแผ่นจำลองนำทางผ่าตัด ในกลุ่มการผ่าตัดฝังรากฟันเทียมด้วยวิธีคอมพิวเตอร์ช่วยเหลือผ่านการจดจำ จะจำลองการวางตำแหน่งรากฟันเทียมโดยใช้โปรแกรมเดียวกับที่ใช้วางแผนการผ่าตัดฝังรากฟันเทียมในกลุ่มคอมพิวเตอร์ช่วยเหลือแบบสถิต แต่การผ่าตัดจะดำเนินการในลักษณะมือเปล่า หลังทำการผ่าตัด มุมของรากฟันเทียมที่เบี่ยงเบนไป ความเบี่ยงเบนที่ตำแหน่งบ่าและปลายรากฟันเทียมจะถูกวัด โดยอาศัยภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ลำรังสีรูปกรวยที่ถูกถ่ายหลังทำการผ่าตัด ที่นำมาซ้อนทับกับภาพรังสีที่ถูกถ่ายก่อนการผ่าตัดในโปรแกรมเดียวกับที่ใช้วางแผนตำแหน่งรากฟันเทียม

ผลการวิจัย: ในกลุ่มการผ่าตัดฝังรากฟันเทียมด้วยวิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตพบว่ามุมของรากฟันเทียมเบี่ยงเบนไป 3.1 ± 2.3 องศา ความเบี่ยงเบนที่บ่าของรากฟันเทียมเท่ากับ 1 ± 0.6 มิลลิเมตร และความเบี่ยงเบนที่ปลายของรากฟันเทียมเท่ากับ 1.3 ± 0.6 มิลลิเมตร ส่วนในกลุ่มการผ่าตัดฝังรากฟันเทียมด้วยวิธีคอมพิวเตอร์ช่วยเหลือผ่านการจดจำพบว่ามุมของรากฟันเทียมเบี่ยงเบนไป 6.9 ± 4.4 องศา ความเบี่ยงเบนที่บ่าของรากฟันเทียมเท่ากับ 1.5 ± 0.7 มิลลิเมตร และความเบี่ยงเบนที่ปลายของรากฟันเทียมเท่ากับ 2.1 ± 1.0 มิลลิเมตร พบความแตกต่างอย่างมีนัยสำคัญทางสถิติที่ทุกตำแหน่งระหว่างทั้ง 2 กลุ่ม

สาขาวิชา	ศัลยศาสตร์ช่องปากและแม็กซิลโลเฟเชียล	ลายมือชื่อนิสิต .....
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5975827332 : MAJOR ORAL AND MAXILLOFACIAL SURGERY
KEYWORD: dental implant, static computer assisted implant surgery, mental computer assisted implant surgery, accuracy of implant surgery

Palita Smitkarn : COMPARATIVE STUDY OF THE ACCURACY OF SINGLE TOOTH IMPLANTS PLACED BETWEEN STATIC AND MENTAL COMPUTER ASSISTED SURGERY. Advisor: Assoc. Prof. ATIPHAN PIMKHAOKHAM, D.D.S. Ph.D.

Objective: This randomized controlled clinical trial aimed to compared the accuracy of implant position between static and mental Computer Assisted Implant Surgery (CAIS) in single tooth gap.

Materials and methods: 52 patients who received 60 implants in single tooth gap, randomized equally into static or mental CAIS. In static CAIS group, data from CBCT scan and data from intraoral or model scan were utilised for the three dimensional virtual planning implant positioning and desiring of a three dimensional surgical guide in implant planning software. Implant bed preparation and implant insertion were done through the three dimensional surgical guide. Implants in the mental CAIS group were virtually planned in the same software, but surgery was done in freehand manner. After the surgery, postoperative CBCT was superimposed onto preoperative CBCT. Deviation in angle, implant shoulder and apex between planned and final implant positions were measured and compared in the same software.

Results: In static CAIS group, mean angle deviation, 3D deviation at implant shoulder and implant apex were 3.1 ± 2.3°, 1.0 ± 0.6 mm and 1.3 ± 0.6 mm, respectively. In mental CAIS group, mean angle deviation, 3D deviation at implant shoulder and implant apex were 6.9 ± 4.4°, 1.5 ± 0.7 mm and 2.1 ± 1.0 mm respectively. Statistically significant differences were found in all dimensions between two groups.

Conclusion: Static CAIS demonstrated higher accuracy of implant positioning

Field of Study: Oral and Maxillofacial Surgery Student's Signature .....
Academic Year: 2018 Advisor's Signature .....

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Palita Smitkarn

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

CT	Computed Tomography
CBCT	Cone Beam Computed Tomography
MSCT	Multislices Computed Tomography
CAIS	Computer Assisted Implant Surgery
3D	Three Dimensional
DICOM	Digital Imaging and Communications in Medicine
STL	Standard Tessellation Language
CAD/CAM	Computer-Aided Design/Computer-Aided Manufacturing
SLA	Stereolithographic
°	Degree
mm	Millimeter
ITI	*International Team for Implantology*
SD	Standard Deviation

CHAPTER 1

INTRODUCTION

1.1 Background and rationale

Dental implants have been used to replace missing teeth since the mid-1960s, in recent years, their use has become much more widespread. They can be used to support crowns replacing single missing teeth, bridges, or even supported dentures. Implants have a number of important advantages over conventional crowns, bridges and dentures such as function, feeling and looking like natural teeth, do not need to preparing adjacent teeth, reduce the load on the remaining oral structures/teeth, and preservation natural bone etc. Therapeutic goal of dental implant is to support restorations and to provide patient function, esthetic, and comfort and to assist in the ongoing maintenance of the remaining intraoral structures (1).

Success of dental implants depend on many factors such as systemic diseases (e.g. uncontrolled diabetes, immunosuppression or certain medication like bisphosphonates), local factors (e.g. radiotherapy, smoking, occlusal trauma, parafunctional habits, periodontal disease, bone quality and density, soft tissue biotype etc.), oral hygiene of the patient, initial stability of the implant at the time of placement, and precise implant placement (2, 3).

Among these, the precision of three dimensional (3D) implant position related to restoration is the most importance factor. The optimal positioning of the implant can allow for favorable prosthetic outcomes, such as function, esthetics, occlusion and implant loading patterns. Moreover, correct implant positioning is essential to ensure a prosthesis design compatible with long term maintenance and access for adequate oral hygiene (3-5).

Proper planning prior to the implant surgery and precise transfer of the planned position under the clinical settings are the keys to ensure accurate implant position. In conventional implant surgery, this has been achieved with the use of a

radiographic stent with radiopaque marker, produced from duplicating the wax-up of the ideal prostheses on study models. The radiographic stent is then worn by the patient during the preoperative Cone Beam Computed Tomography (CBCT) scan, thus allowing to transpose the ideal prosthesis shape on the alveolar ridge and indicating the ideal prosthetic position for the implant. The radiographic stent can be thereafter transformed into surgical stent, allowing the surgeon to visualize the ideal prosthetic position intraoperatively. In general, the surgeon decides in situ on the chosen implant position once the flap is raised and the bone is exposed (6). The limitation of this technique is that the final angulation, depth and position of the implant is decided by the surgeon intraoperatively. Possible surgical stent is only used as a supplementary means to visualize the prosthetic position. Thus this technique is often described as "freehand" and the accuracy of implant final position depends on surgeon's skill and experience.

Recently, advanced digital technology for preoperative implant planning called static Computer Assisted Implant Surgery (static CAIS) that allow for simultaneous visualization of two dimensional reformatted images and three dimensional bone and teeth morphology have been proposed (7). This technique utilizes computer technology for the virtual planning of the implant position prior to the surgery accounting for bone quality and quantity, location of anatomical structures, soft tissues, teeth and functional and esthetic demands of future prosthesis (8). During the surgical intervention, the planned implant position is transferred to the surgical site by three dimensional printed surgical guide. Angulation and depth of implant osteotomy is controlled by guided surgical drills through a metal sleeve embedded in the surgical guide. The surgeon cannot change the plan during surgical intervention (9). The advantages of static CAIS are implant is virtually planned in three dimensions prior the surgery, decrease human error, and prevents injury of important structure such as mandibular nerve damage, sinus perforations, bone fenestrations, bone dehiscence and adjacent tooth root damage (7, 10, 11). On

the other hand, deviation from the planned position can still occur due to a variety of reasons such as imprecision while acquiring or processing optical and radiographic imaging data, inaccuracy in the surgical guide fabrication, deficient fit or movement of the guide during surgery and human error (12, 13).

From the problems of conventional implant surgery that the surgeon do not know the design of planning implant position in three dimensions, Vercruyssen M et al., in 2014, 2015 reported the 'mental CAIS' system which mimic to static CAIS, the implant is virtually planned in implant planning software program in three dimensional directions, however the guided template does not prepare for the surgery (14, 15). The surgical intervention is done in freehand manner. The advantage of this system over the conventional implant surgery is the implant is virtually planned in implant planning software program before the surgical intervention resulting in it can compare the deviation of implant position.

Although currently static CAIS is gaining popularity in the practice of implant dentistry, concerns about its accuracy are still not fully addressed (5, 16). The accuracy of the position for dental implants placed by static CAIS has been investigated in recent studies (5, 7, 15, 17-20). These studies have reported high accuracy and better implant positioning with the use of static CAIS, with however a wide diversity of outcomes, as different settings have been utilized in most studies. At present only one clinical randomized trial has compared the accuracy of implant position between static CAIS and conventional implant surgery in single tooth gap, albeit with a small patient sample (18). Taken together, there is a further need of clinical data from randomized studies to support our understanding of accuracy of static CAIS in single tooth gap and the factors of importance for decision making in clinical settings.

Thus the objective of the study was to investigate the accuracy of implant position by using the deviation compare between static and mental CAIS in single tooth implant.

Keywords

Computer Assisted Implant Surgery (CAIS), Static CAIS, Mental CAIS, Accuracy of implant position

1.2 Research question, Research objective, Research hypothesis

This study measured accuracy of implant position between planned and placed dental implants in 9 positions;

- Angle deviation
- Deviation at implant shoulder - 3D
- Deviation at implant shoulder - mesio-distal direction
- Deviation at implant shoulder - bucco-lingual direction
- Deviation at implant shoulder - apico-coronal direction
- Deviation at implant apex - 3D
- Deviation at implant apex - mesio-distal direction
- Deviation at implant apex - bucco-lingual direction
- Deviation at implant apex - apico-coronal direction

1.2.1 Research question

Is there any difference of the deviation of implant position between planned and placed dental implant between static and mental CAIS in single tooth gap?

1.2.2 Research objective

The purpose of this study was to compare the accuracy of implant position between static and mental CAIS in single tooth gap.

1.2.3 Research hypothesis

There is difference in deviation of the implant position between planned and placed implant between static and mental CAIS in single tooth gap.

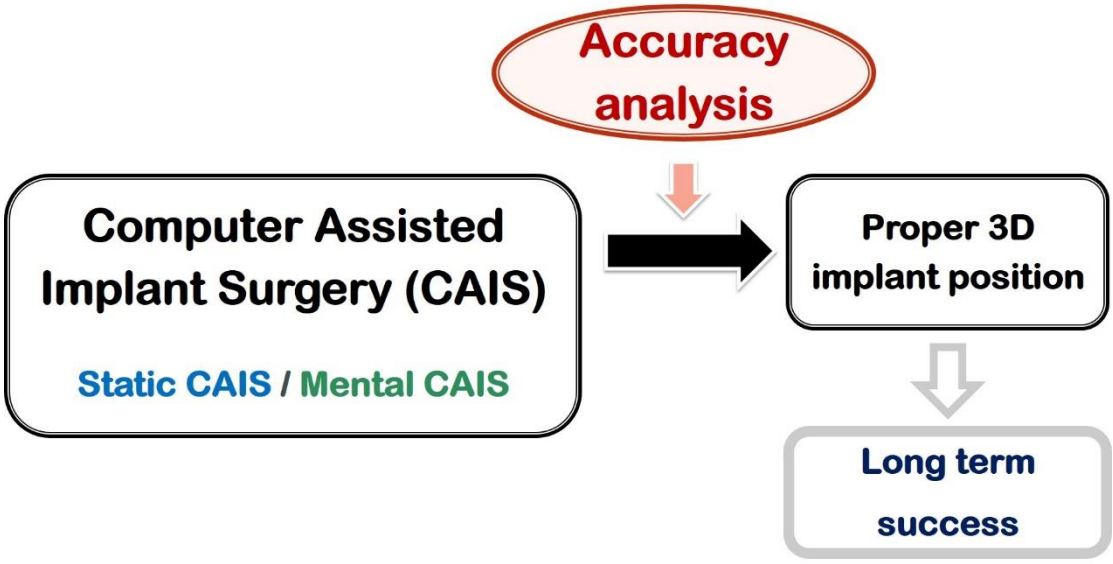
1.3 Research design

Prospective randomized controlled clinical trial

1.4 Expected benefits

- The information about the accuracy of implant position between patients who receiving static and mental CAIS in single tooth implant.
- If the static CAIS group appears more accurate results, it will make sure that guide template is an important instrument for high accurate implant surgery especially in area that required esthetic outcome or nearby vital structure.
- If the mental CAIS group appears more accurate or no different in results, guide template will not be necessary to fabricate for implant surgery. It can decrease patient's expenditure and it do not necessary to take time for fabrication the guide template.

1.5 Conceptual framework



CHAPTER 2

REVIEW LITERATURES

2.1 Dental implant

Dental implant is a prosthetic replacement for a missing tooth which is placed within jaw bone to support a dental prosthesis such as a crown, bridge, denture, or to act as an orthodontic anchor. There are commonly three parts to what is described as an implant (Fig 1).

- Implant body, which is inserted directly into the bone, has three parts.
  - First part is a platform (also called head, neck, shoulder, coronal portion or crest module). The platform is designed to retain prosthetic component and to create transitional zone to load-bearing implant body.
  - Second part is a body. The body of dental implant is designed in tapered or cylindered form, threaded or non-threaded type.
  - Third part is an apex. The apex of dental implant is the part which is most deeply submerged in bone. The design of this part can be flat, V-shaped or round.
- Abutment is a piece that connects the implant device to the prosthesis. Abutments can be angled or straight, depending on axial relationship between implant body and abutment.
- Prosthesis
  - Crown is a restoration for single implant replacing single tooth.
  - Bridge is a restoration for replacing multiple missing teeth.
  - Suprastructure is a metal or zirconium framework that attaches to implant abutment. It provides retention for removable prosthesis.
  - Overdenture is a denture that is supported either by prepared tooth root covered by coping or by implants with specific attachments that fit into reciprocal attachments in denture (21).

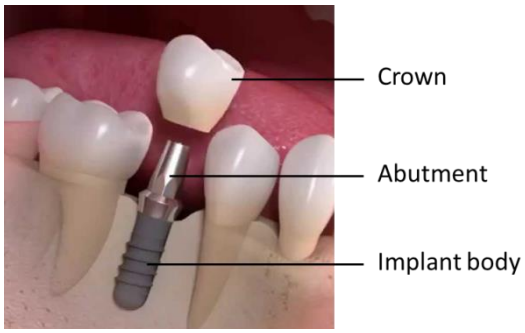


Figure 1 Graphic demonstrates anatomy of dental implant (17)

The phenomenon of osseointegration of titanium implants was discovered by a Swedish orthopaedic surgeon, P I Brånemark, in 1952 who defined osseointegration as "*a direct structural and functional connection between ordered living bone and the surface of a load-carrying implant*". He found this discovery accidentally in 1952 when he was studying blood flow in rabbit femurs by placing titanium chambers into their bone and could not be remove from the bones after a period of healing (22). He brought this idea into the dentistry. Brånemark placed implants in his first patient in 1965, who had cleft palate, jaw deformity and congenitally missing teeth in lower jaw. Four implants were inserted into the mandible to allow him to use denture. These implants integrated within a period of six months and remained in place for the next 40 years (23).

2.2 Factors influencing the treatment outcomes of implants

The main objective of implant therapy is to achieve successful treatment outcomes with high predictability and low risk of complications, both in functional and esthetic outcome. The other objectives are the least possible number of surgical interventions, low morbidity for the patient, and short treatment period between tooth extraction and prosthetic restoration. Various efforts have been made in the past 10 to 15 years to modify treatment protocols to make implant therapy more attractive to patients and to increase patients acceptance of this treatment modality.

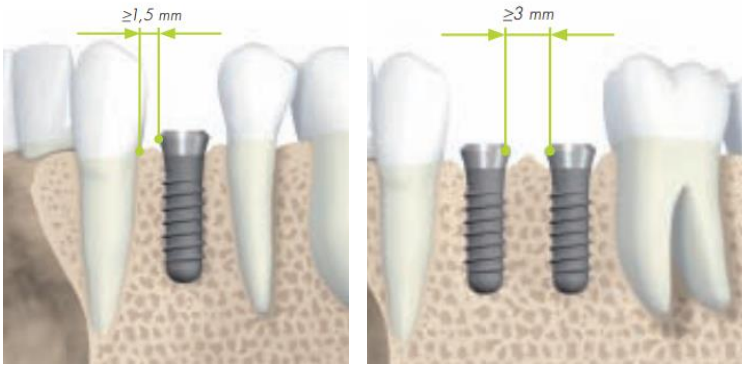
However, the modifications should not compromise the predictability of successful outcomes or the risk of complications (24).

2.2.1 Implant position and spacing

Preserving an adequate blood supply to the bone around dental implant is a critical factor to dental implant success. Presence of biologic width around dental implant like in a natural tooth help bone exposed to the oral cavity will always cover with periosteum and connective tissue (25).

The importance of the implant position can be manifested in the four dimension: mesio-distal, bucco-lingual, apico-coronal location and implant angulation (26). The ultimate goal is not only to avoid adjacent important structures, but also to respect the biological principles that have been established to achieve esthetic and functional outcomes.

For mesio-distal criteria, a minimum distance of 1.5 mm between implant and adjacent teeth and a minimum distance of 3.0 mm between two implant has been recommended to avoid iatrogenic damage to adjacent teeth, to preserve crestal bone and interproximal papillary height, and to provide proper osseointegration and gingival contours (Fig 2) (Table 1) (2, 27).



(a) (b)

Figure 2 Graphic demonstrates mesio-distal implant position
(a) Minimum distance of 1.5 mm between implant and existing dentition
(b) Minimum distance of 3 mm between two adjacent implants

For bucco-lingual criteria, bucco-lingual implant position is often determined by the gingival biotype, occlusal relationship with opposing teeth, and desired emergence profile. A thickness of labial bone more than 1.0 mm in area of non-esthetic zone and 2.0 mm in area of esthetic zone has been recommended to maintain hard and soft tissue profile and increase of an esthetic outcome (Fig 3) (Table 1) (2).

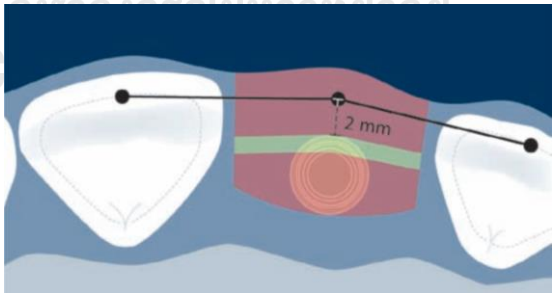


Figure 3 Graphic demonstrates bucco-lingual implant position
The facial extent of the implant shoulder is about 1.5–2 mm orally to the point of emergence of the adjacent teeth (within the green comfort zone) (2)

For apico-coronal criteria, the apico-coronal positioning of the implant shoulder follows the philosophy “as shallow as possible, as deep as necessary”. Agreement

with the *International Team for Implantology* (ITI) consensus meeting, the position of the implant shoulder should be approximately 3 mm apical to the midfacial gingival margin of the planned restoration or apical to the CEJ of an adjacent tooth (Fig 4) (2). The implant length should allow an adequate safety margin of approximately 2 mm of bone between the apical end of the implant and neurovascular, particularly as many drills are designed to prepare the implant site slightly longer than the chosen implant (Table 1).

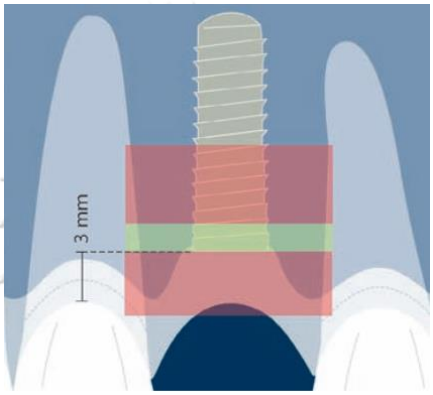


Figure 4Graphic demonstrates apico-coronal implant position
The implant shoulder should be positioned about 3 mm apical to the gingival margin of the contralateral tooth in patients without gingival recession (2)

Table 1 Recommendation minimum distance of the implant to other structures

Position	Distance (mm)
Implant to tooth	1.5
Implant to implant (fixed restoration)	3.0
Implant to facial/lingual bone	
non esthetic zone	1.0
esthetic zone	2.0
Implant to vital structure	2.0

For implant angulation, Implant angulation is particularly important in treatment planning for screw-retained restorations. Osteotomy and placement of the

implant against the dense bone of the palate can lead to unintended buccoversion of the implant and should be considered at implant placement (4).

2.2.2 Periodontal status

Seibert and Lindhe described the term of “gingival biotype” in 1989. In natural teeth, a thin-scalloped gingival biotype associates with narrow zones of keratinized gingiva tissue. While a thick-flat periodontal biotype associates with wide zones of keratinized gingiva tissue (28). Thick biotypes have more resistance to recession and able to concealed the color of the metal implant. (29).

Bouri A Jr et al., in 2008 determined association between the width of keratinized mucosa and the health of implant-supporting tissues. They found that implants in area of ≥ 2 mm of keratinized tissue showed less alveolar bone loss and more healthy soft tissue than implants in area of < 2 mm of keratinized tissue. (30).

In a systematic review of implant outcomes in treated periodontitis subjects from Ong et al., in 2008, they concluded that there is some evidence that stated periodontitis treated patients have more implant loss and complications around implants than in non-periodontitis patients (31).

2.2.3 Occlusal pattern

Occlusion is one of critical factor for implant longevity because of the nature of attachment of the bone to the titanium-surfaced implant. In the natural tooth, the periodontal ligament has capacity to absorb stress and allow for tooth movement, but the osseointegration of bone-implant interface has no capacity to allow movement of implant. If any stress from occlusal force exceeds the capacity to absorb stress, the implant will fail (32).

Occlusal overload, premature occlusal contact, occlusal contact on an inclined plane and parafunctional habits (i.e. bruxism, clenching, grinding etc.) are one of the main causes for peri-implant bone loss and implant failure due to increase the magnitude of stress in bone and increased the tensile crestal stress (33, 34).

2.2.4 Implant stability

Implant stability is usually divided into two stages: primary and secondary stability. Primary stability, occurs at implant surgery, is a mechanical phenomenon that related to the bone quality and quantity, the type of implant and placement technique used. The changeover from primary stability to secondary stability occur when deposition of new bone (osseointegration) at implant/tissue interface. During healing period, primary stability trend to decrease, while secondary stability trend to increase. The gradual shift from primary stability to secondary stability is poised at around 4 weeks, this is the least stable time point (stability dip). Any micromovement of the implant during this transitional phase lead to the failure of osseointegration (Fig 5) (35, 36).

In the past clinical implant protocols, osseointegration is achieved by long initial healing periods (3–6 months) in which implants remain unloaded to assure an undisturbed bone apposition. The development of new implant surfaces and improved surgical techniques has changed this paradigm by improve the primary stability at the time of implant insertion and reduce the initial unloaded healing period (Fig 6) (37).

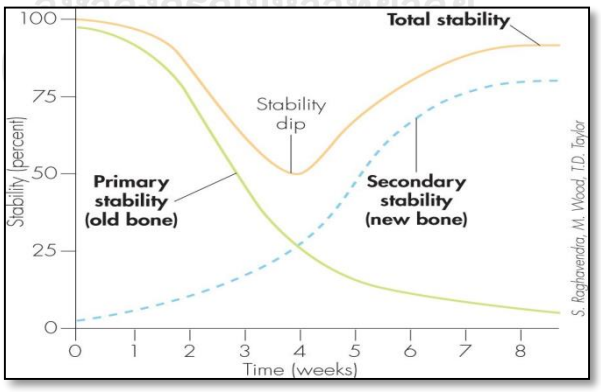


Figure 5 Graphic demonstrates stability of dental implant over time

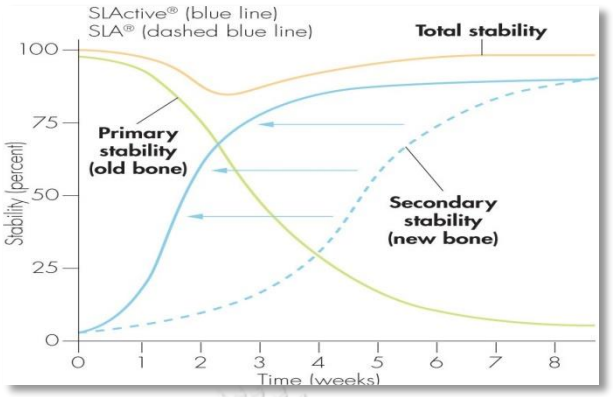


Figure 6 Graphic demonstrates stability of new dental implant surface over time

2.3 Implant complication related to malposition

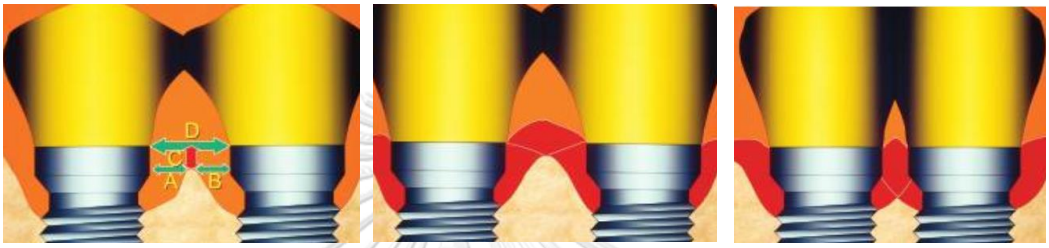
The malposition of dental implants contribute to implant and component complications in two ways. One is the malposition of the implant within available bone causes the implant to biologic failure. Another is malposition of the implant relative to planned tooth or prosthesis position. This causes the implant to esthetic failure, biologic failure by hard to cleaning, and/or mechanical/technical failure by increasing the forces acting within the prosthesis (4).

The malposition of dental implant has been defined in 4 positions; mesio-distal direction, bucco-lingual direction, apico-coronal direction, and angulation.

2.3.1 Mesio-distal implant malposition

An implant is placed too close to an adjacent natural tooth (less than 1.5 mm) and too closed between two implants (less than 3 mm) can resorb inter-implant bone crest and not have enough space for developing soft tissue. Resulting in, complete absence of a papilla and bone loss in termed of “bone saucer”. Bone saucer has a horizontal component of 1.0–1.5 mm, whereas the vertical component measures around 2–3 mm (2, 38). Tarnow et al., in 2007 stated that if space between two implants is less than 3 mm, it can cause inter-implant crestal bone loss (Fig 7) (27).

Moreover, malposition of implant in mesiodistal direction can lead to limitation of implant or abutment impression by interference of impression copings and improper design of prosthodontics restoration such as improper crown contours and open contact causing plaque accumulation at the adjacent tooth and subsequent interproximal caries, which are often initiated on the root surface of the tooth (4).



(a) (b) (c)

Figure 7 Graphic demonstrates mesio-distal implant position between two implant (a) Radiographic measurements recorded. A and B represent the lateral distance (bone loss) from implant to bone crest, C represent vertical crestal bone loss, and D represent distance between implants at the implant-abutment interface. (b) Inter-implant distance greater than 3 mm. Lateral bone loss from adjacent implant does not overlap, with minimal resultant crestal bone loss. (c) Inter-implant distance 3 mm or less. Lateral bone loss from adjacent overlap, with resultant increase in crestal bone loss (27).

2.3.2 Bucco-lingual implant malposition

A bucco-lingual malposition of an implant can cause two different complications. One is an implant placed too far labially causing bone dehiscence, fenestration and gingival recession. These effect to esthetic outcomes and lead to removal of the implant finally.

Another is implant placed too far lingually can cause ridge-lap design prosthesis that make the patients difficult to maintain plaque control and make unesthetic outcomes (2, 39).

2.3.3 Apico-coronal implant malposition

An apico-coronal malposition can cause two different complications. The first is placed too shallow that can visible metal implant shoulder, causing an unpleasant esthetic outcome (2, 4). Additionally, potential problems occur in producing crowns with insufficient retention on custom abutments or sufficient space to mask screw access because insufficient restorative dimension can be occured (4).

The second complication is implant placement too deep into the bone tissues. This leads to persistent inflammation of the peri-implant mucosa, difficulty to maintain adequate plaque control, recession of the labial mucosa and crestal bone. Moreover, it is difficult to seat an impression coping/abutment leading to laboratory errors and complications such as incomplete seating of the abutment that risk to infection from gap between implant body and abutment (2, 4). Moreover, too deep implant may iatrogenic damage to relative anatomical structure such as paresthesia from mandibular nerve injury and maxillary sinusitis from implant invades into sinus or Schneiderian membrane perforation (40).

2.3.4 Mis-axis

Too far labially inclined implant is often associated with buccal bone dehiscence followed by recession of the labial mucosa or infection. If the axis problem is minor, the problem can be corrected by using angled abutments. If the axis problem is severe, the complication is usually very difficult or impossible to resolve. Too far lingually inclined implant results in unhygienic and unesthetic prosthetic design. Too far mesially or distally inclined implant can damage adjacent tooth root. If a drill and/or implant fixture invades the PDL or tooth root, this will lead to root resorption or devitalization of adjacent teeth (2).

Distribution of forces on implants must be adhered remarkably along the implant. Off-axis inclination contributes to overloading of prosthesis (41). Implant failure is a consideration if the axis change more than 25 degrees, because offset loading lead to shearing forces that bone cannot tolerate (42).

Table 2 Implant complication related to malposition

Position		Complications
Mesio-Distal		Crestal bone loss
		Absence of papilla
		Prosthesis: improper design
Bucco-Lingual	Too buccal	Bone dehiscence
		Fenestration
		Gingival recession
	Too lingual	Prosthesis: ridge-lap design
Apico-coronal	Too shallow	Visible metal implant shoulder
	Too deep	Recession of labial mucosa and crestal bone
		Iatrogenic damage to relative anatomical structure
Axis	Too labially	Buccal bone dehiscence
		Recession of labial mucosa
	Too lingually	Prosthesis: ridge-lap design
	Too mesially/distally	Damage adjacent tooth

2.4 Implant surgery technique

2.4.1 Conventional implant surgery

2.4.1.1 Definition

Conventional implant surgery is the procedure that replaces tooth roots with screw-like posts by using oral examination and radiographic interpretation for analyzing the soft tissue, bone and relative anatomical structures without using with implant planning software for virtual planning, guiding or performing surgical interventions in three dimensional directions.

Periapical radiograph, panoramic radiograph and Cone Beam Computed Tomography (CBCT) data are used to assess the bone available for implant placement as well as the surrounding anatomy. Traditionally, periodontal probes, gauges or calipers have been used during the intraoral examination for bone sounding, which offers a reasonable idea of the height and thickness of

the ridge. Further, the surrounding teeth can be used as guides for determining the correct positioning of the implant.

A study cast can be fabricated, upon which measurements can be made to provide a better understanding of the mesial-distal and apico-coronal space available for placing the implant. Additionally, a diagnostic wax-up of the ideal prosthesis can be conducted. A radiopaque stent is produced from the wax-up which the patients wear during the CBCT examination. Then surgical stent is produced, allowing the surgeon to visualize the ideal prosthetic position at the time of surgery.

However the conventional implant surgery has weakness such as surgical stent is fabricated from diagnostic wax-up without reference from underlying anatomical structure, the surgeon unable to control implant angulation and depth during surgery lead to inaccuracy of implant position and harmful to adjacent structure, and the implant does not virtually plan in three dimensional directions lead to the surgeon does not know the definite design of planning implant position in three dimensions and unable to compare implant position between planned and placed dental implant.

2.4.1.2 Surgical procedures

Implant selection is based on anatomic site analysis that comes from diagnostic model or radiographic interpretation in mesio-distal, bucco-lingual, and apico-coronal directions.

Under local anesthesia, the mucoperiosteal flap is opened with a crestal incision and extended through the sulcus of adjacent teeth. Implant bed preparation begins with preparing the alveolar ridge. For the precise position, implant site is marked with the small round bur. After that, the implant bed preparation is drilled with pilot and twist drills of increasing diameter, according to the implant diameter chosen in the preoperative planning. Then fine implant bed preparation is done. Follow by placing the implant with handpiece and/or

ratchet. An appropriate cover screw or healing cap is closed. Prior to completion of the surgical procedure, the mucoperiosteal flap is repositioned precisely and tension-free suturing. Following the surgery, 2D radiograph is taken to examine the position and direction of the placed implant and its relationship to the roots of adjacent teeth (43).

2.4.2 Static Computer Assisted Implant Surgery (static CAIS)

Universal key for success of implant is determined mainly by accurate positioning of implant placement. This depends on clinician's ability to translate the ideal implant position from the diagnostic tools like x-rays, Computed Tomography (CT), and Cone Beam Computed Tomography (CBCT) scan to actual anatomic location in the jaw without trauma to relative anatomical structures and satisfied both function and esthetic outcomes.

In conventional implant surgery, inappropriate surgical stent preparation, movement of stent during surgery, lack of reproducibility in terms of positioning the stent leads to imprecise implant placement and finally leading to implant complications and failure (44).

All of these problems lead to the developing of digital technology for preoperative implant planning called static Computer Assisted Implant Surgery (static CAIS).

2.4.2.1 Definition

Static Computer Assisted Implant Surgery (static CAIS) is a method that using patient's CT or CBCT image and surface scan data in combination with implant planning software for virtual planning of the implant position prior to the surgery with the optimal implant size and position regarding surrounding vital anatomical structures, bone thickness and future prosthetic needs (3). During the surgical intervention, the planned implant position is transferred to

the surgical site by 3D printed surgical guide. No intraoperative position changes can be made with this system (9, 18-20, 45).

This technique offers several benefits over the conventional approach such as precise implant positioning, possible to surgery with flapless approach, prevents injury to important structure (e.g. mandibular nerve, maxillary sinus, adjacent tooth root), provisional restorations can be fabricated prior to the surgery, and reduction of the error from technique sensitive and operator's skill. Moreover, it has reported that less patient discomfort than conventional method (46, 47).

The disadvantages are the surgeon unable to change implant position or surgical plan as need, need wide mouth opening especially in posterior teeth due to long surgical drill, longer initial treatment time, reduction of predictability of implant positioning with sufficient implant stability from under- or overestimation of bone volume during CT-data analysis and virtual implant planning, and irrigation is limited during implant site preparation (20, 47). Margonar et al., in 2010 evaluated bone tissue heating and the wear drills after repeated osteotomies for implants. They simulated the guided surgery technique and compared it with the conventional technique. According to that study, the heating of the bone tissue due to the guide surgery technique was higher when compared with the conventional surgery during the preparation of the surgical site, but both techniques have not reached the threshold temperature that causes immediate tissue necrosis (48).

2.4.2.2 Implant planning program

Implant planning program is a tool for virtually planned implant and desired 3D surgical guide. The program use Digital Imaging and Communications in Medicine (DICOM) from CT or CBCT scan in combination with Standard Tessellation Language (STL) from surface scan data.

The program allows visualization and manipulation of the images of the patient's jaw bone and surrounding tissue in 3D directions that makes possible the most accurate approach to implant surgery. Surgeon can virtually planned implant position and measured the distance between implant and relative anatomical in the program. This visualization allows for rapid site analysis and predictable treatment planning whereby the surgeon can order specific implant size and diameter, healing abutment, and provisional crown.

At present, third-party software programs are now available from many manufacturer, for example coDiagnostiX (Dental wings inc, Montreal, Canada), Implant Studio (3shape, Copenhagen, Denmark), Invivo5 (Anatomage, San Jose, CA, USA), Simplant (Materialise Dental Inc, Glen Burnie, MD, USA) and NobelClinician (Nobel Biocare, Goteborg, Sweden). There are also some companies that provide treatment planning in the proprietary software of the CBCT units such as Galileos system (Sirona Dental Systems, Inc, Charlotte, NC, USA), TxSTUDIO software (i-CATÒ, Imaging Sciences International LLC,Hatfield, PA) and NewTom implant planning software (NewTom, Verona, Italy).

The different computer guided systems can also be differentiated in terms of their respective design for the drill guidance through the template. For example, some systems such as coDiagnostiX, Simplant use surgical templates with sleeves of an increasing diameter, while others such as SKYplanX (Senden, Germany) design different drills with stops to achieve depth control. Some systems such as coDiagnostiX, Procera (Nobel Biocare, Göteborg, Sweden) allow a guided implant placement (53) whereas in other systems such as StentCad (Media Lab Software, La Spezia, Italy), the implants are inserted without using a guided device (6).

The coDiagnostiX software (Dental wings inc, Montreal, Canada) is intended to be used for pre-operative planning of dental implant installation and restoration. The performance of this software depends on the quality and

accuracy of the CBCT radiograph as well as the surface scan data (Fig 8). Moreover, post-operative radiograph can be superimposed onto pre-operative radiograph by treatment evaluation function in the program for comparing accuracy of implant placement in 3D position (Fig 9).

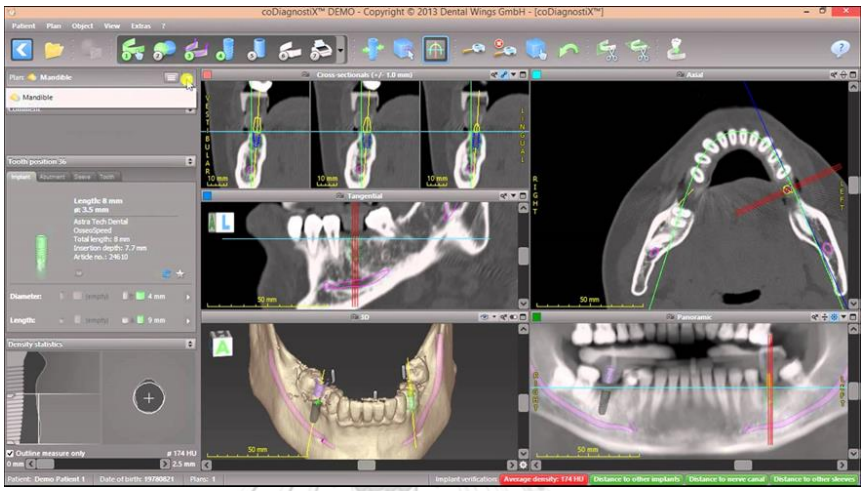


Figure 8 coDiagnostix software (Dental wings inc, Montreal, CA) for virtually planning implant position and desiring the 3D surgical guide

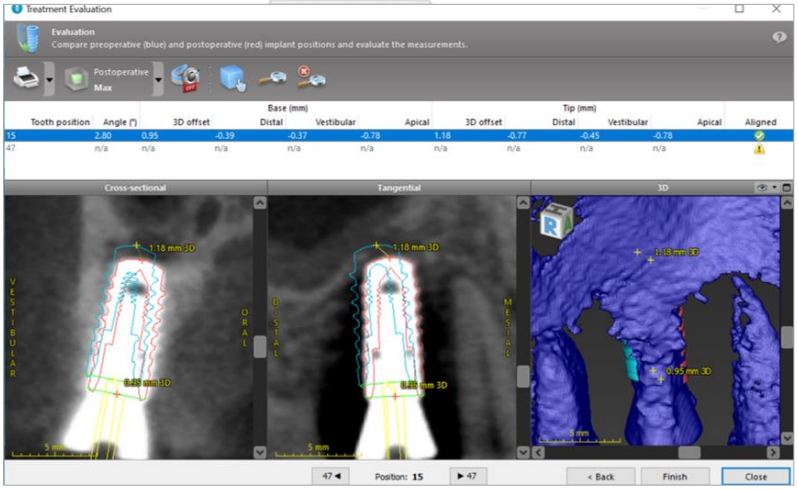


Figure 9 Treatment evaluation mode in coDiagnostix software (Dental wings inc, Montreal, CA) for measuring the deviation of implant position

2.4.2.3 Three dimensional surgical guide

DICOM data from CBCT imaging can show the detail of hard tissue very well, but soft tissue detail is not displayed as with conventional CT and

sometimes contains artifacts of metal material (49). Fabrication of 3D surgical guide is based on the adjacent teeth and nearby soft tissue. Thus, surface scanning technology is used for providing soft tissue information as well as accurate information of teeth contours because optically scanned are scatter free. The STL file from surface scanning can be imported and superimposed onto the DICOM file in the implant planning software. In the planning software, surgeon chooses implant size and virtually places implant at the ideal position, after that the 3D surgical site is desired and exported for fabrication (7, 19, 50).

Example of CBCT scanning machine is Accuitomo 3D machine (J. Morita Inc., Kyoto, Japan) (Fig 10). The machine has 9 sizes for exposure regions with diameters ranging from 40 - 170 mm and the voxel size are 80 - 250 μm.

There are 2 types of surface scanning machine; model and introral scanner. Example of model scanner is D900 model scanner (3shape, Copenhagen, Denmark) (Fig 11). This scanner has four 5.0 MP cameras that facilitate the exacting accuracy required for high quality production and can capture 3D data in 35 second. Example of intraoral scanner is Trios intraoral scanner (3shape, Copenhagen, Denmark) (Fig 12). This scanner is the spray and powder free intraoral scanning and has capable of measuring shades of teeth and adding HD photos to the 3D mode.

Figure 10 Accuitomo 3D machine (J. Morita Inc., Kyoto, Japan)

Figure 11 D900 model scanner (3shape, Copenhagen, Denmark)

Figure 12 Trios intraoral scanner (3shape, Copenhagen, Denmark)

Technique for fabrication the 3D guide template is stereolithography (rapid prototyping). This technique uses computer-aided design/computer-aided manufacturing (CAD/CAM) technology by laser-driven polymerization process. The stereolithography consists of a vat which contains a liquid photo polymerized resin. A laser which is mounted on top of the vat moves in sequential cross sectional increments of 1 mm, which correspond to the slice intervals which are specified during the CBCT formatting procedure. The laser polymerizes the surface layer of the resin on contact. Once the first slice is completed, a mechanical table which is immediately below the surface, moves down 1 mm, carrying with it the previously polymerized resin layer of the model (51).

2.4.2.4 Factors influence the accuracy of implant placement in static CAIS

2.4.2.4.1 Type of arch (maxilla/mandible)

Behneke A et al., in 2012 (17) studied 19 implants which placed to restore a single-tooth gap in 19 patients for comparing the accuracy between maxilla and mandible. A borderline significant difference was found between maxilla and mandible for the linear deviation at the apex of the implants, which was larger in the maxilla than in mandible (0.50 VS 0.40 mm, P = 0.033), while no significant differences were found for the linear deviation at the coronal or the angular deviation. These low deviations are clinically not meaningful.

This finding is in partial agreement with studies from Ozan O et al., in 2009 (52) and Valente et al., in 2009 (53). They reported implant placed with static CAIS in mandible is more accuracy than in the maxilla.

2.4.2.4.2 Type of edentulous area (single-tooth gap/interrupted dental arch/shortened dental arch/reduced residual dentition)

Farley NE et al., in 2013 (52) stated that low deviations can be observed, if single-tooth gaps with mesial and distal tooth-supported templates are treated. A mean deviation of 0.21 ± 0.16 mm (range 0.01 to 0.92) at the shoulder of the implant, 0.32 ± 0.34 mm (range 0.03 to 0.59) at the apex of the implant, and 1.35° ± 1.11° (range 0.07° to 3.33°) of the angular deviation were reported.

Behneke A et al., in 2012 (17) compared the deviation according to kind of template. They stated that single-tooth gap templates had the highest accuracy. Secondary was in free ending templates and shortened dental arch. The last is in residual dentition templates. Moreover, the amount of deviation was at least twice as large for reduced residual dentition templates as for single-tooth gap templates.

This observation agrees with the previous findings from Ersoy et al., in 2008 (7), reported that single tooth gap supported had higher accuracy than free-ending tooth supported templates. A mean error of 0.74 ± 0.40 mm at the implant shoulder, 1.66 ± 0.28 mm at the implant apex, and an angular deviation of 3.71° ± 0.93° for nine implants placed with single tooth gap supported templates; and 1.23 ± 0.67 at the implant shoulder, 1.59 ± 0.74 at the implant apex, and an angular deviation of 4.78° ± 1.86° for 20 implants placed with free-ending tooth supported templates in Kennedy Class I or II partial edentate patients.

Farley NE et al., in 2013 (52) stated that a wider deviation was reported for sites with a reduced residual dentition, as only a few teeth supported the guide that made less stability. Moreover, larger deviation for templates with unilateral anchorage could be expected due to tilting and bending of the template itself.

2.4.2.4.3 Type of guided surgery (fully guided placement/freehand placement/freehand dilation of the borehole)

The use of the template can be limited to guide the pilot drilling or for the entire osteotomy up to the implant placement. Nevertheless, in situations with limited mouth opening or restricted interarch space, surgical guide templates may interfere with the effective use of the drills in the posterior quadrants and therefore the templates may be used only for the initial steps of osteotomy. This may affect the overall accuracy of the procedure.

Behneke et al., in 2012 (17) reported mean deviation at the implant shoulder for each of the freehand final drilling, freehand implant insertion, and full guided implant insertion groups were 0.52, 0.30, and 0.21 mm, respectively. At the implant apex, they were 0.81, 0.47, and 0.28 mm, respectively. They concluded that increase in the

number of sleeve-guided site preparation steps made a higher accuracy, hence implant placement through the guide allowed a more accurate implementation of the virtual plan to the surgical site than freehand insertion or freehand final drilling.

2.4.2.4.4 Type of surgical guide support (tooth- supported/bone-supported/mucosa-supported)

The types of guide supported template are classified into 3 types; tooth- supported, bone-supported, and mucosa-supported (Fig 13). Selection bases on the number of remaining teeth for supporting guide and on the need for a flapless approach.

Ozan et al., in 2009 (53) compared the accuracy of 3 different types of stereolithographic surgical guides. The deviations at implant apex were 0.95 ± 0.6 mm, 1.57 ± 0.9 mm, and 1.60 ± 1.0 mm for the tooth-supported, bone-supported, and mucosa-supported surgical guides, respectively. The angular deviations were 2.91° ± 1.3°, 4.63° ± 2.6°, and 4.51° ± 2.1° for the tooth-supported, bone-supported, and mucosa-supported surgical guides, respectively. Significant differences were found between tooth-supported and bone-supported, and between tooth-supported and mucosa-supported surgical guides. They concluded that tooth-supported surgical guides were more accurate than bone- or mucosa-supported surgical guides.

The third EAO Consensus Conference 2012 (54) concluded that tooth-supported guide tends to be slightly more accurate than mucosa-supported and bone-support-guides, but the differences are small.

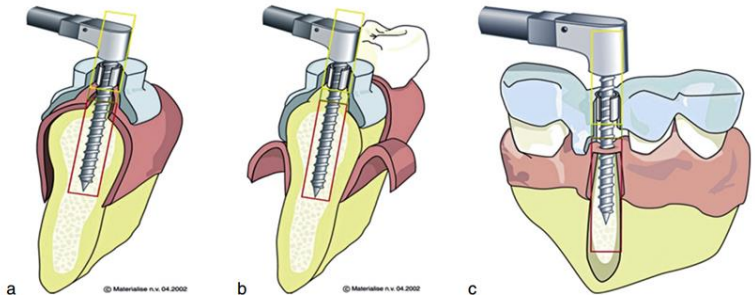


Figure 13 Graphic demonstrates type of guide support template (a) mucosal-supported; (b) bone-supported; (c)tooth-supported (55)

2.4.2.4.5 Surgical technique (flapless/open flap)

Prospective clinical study from Behneke et al., in 2012 (17) that compared flapless implant placement technique when the soft tissue was punched with the full thickness flaps were raised. A borderline significance (P = 0.027) was found between both conditions for the implant neck radial deviations (slightly higher values for the flapless approach). For the linear deviation at the implant apex, and for the angular deviation, no significant differences were found. They concluded that flap elevation did not negatively influence the positioning of the tooth-supported surgical templates. These findings are in agreement with the results reported by the study of Ersoy et al., in 2008 (7) who studied in vivo study for partially or completely edentulous patients. They could not find any difference in accuracy for the open flap procedure and the flapless procedure.

Moreover, flapless surgery seems to benefit peri-implant mucosal conditions, particularly in terms of maximum preservation of peri-implant papillae and reduced mucosal recession. However, soft tissue punching and removal was not recommend in patients with lack of keratinized attached mucosa and close proximity to any major

anatomical structures, and lack of bucco-palatal dimension of the ridge (56).

2.4.2.4.6 Operator's skill (experienced/inexperienced)

Rungcharassaeng et al., in 2015 (57) evaluated the effect of operator experience on the accuracy of implant placement with a static CAIS on the partially edentulous mandibular model. They stated that no significant differences were found in the angular and linear deviations between experienced and inexperienced operators. Although not statistically significant, the amount of vertical deviation in the coronal direction of the implants placed by the inexperienced operators was about twice that placed by the experienced operators.

Simon H et al., in 2012 (58) studied the effect of surgeon's experience on the accuracy of implant placement with static CAIS in model. They concluded that surgeon's experience had minimal effect on the accuracy of implant placement. The only difference that resulted from surgical experience was that experienced surgeons made less error in bucco-lingual angulation compared to unexperienced and intermediate surgeons.

Choi et al., in 2017 (45) concluded that implant placed after 3 year of experience was significantly more accurate in position, while the 3-year cutoff was not statistically significant to angulation.

2.4.2.4.7 Accuracy of image acquisition (CBCT/MSCT)

Poeschl et al., in 2013 (49) compared the accuracy of CBCT and Multislices Computed Tomography (MSCT) for its use in image-guided surgery in mandibular models. Four precise metal reference markers in each model were scanned with MSCT and CBCT. The six reference

distances between the markers were measured using 3 methods. They found that no significant difference between MSCT and CBCT.

Arisan et al., in 2013 (15) compared the accuracy of MSCT and CBCT in 11 patients with 108 implants in mucosa supported stereolithographic (SLA) surgical guides. They found that no statistically significant differences between the MSCT and CBCT (59). However CBCT has many advantages over MSCT such as lower radiation dose, lower cost, and shorter scanning time.

2.4.2.4.8 Accuracy of surgical guide fabrication

The accuracy of 3D surgical guide fabrication results from the accuracy of impression taking, CBCT scanning, surface scanning, implant planning software, matching the data, transferring the data, CAD/CAM surgical guide production, fitting of surgical guide, and tolerance surgical sleeve/drill (16, 60). For example, if the 3D reconstruction for the creation of the surgical guide is generated with a too low gray value threshold, the surgical template will be thicker than the original radiographic guide, resulting in a higher position toward the alveolar ridge and the implants will be placed to superficial (61). Santler et al., in 1998 stated that overall deviation in the production process of a stereolithographic guide is less than 0.25 mm (62). This finding closed to the study from Sebastian K et al., in 2015 stated that mean deviation from production process of the surgical guide using coDiagnostiX software is 0.22 mm at sleeve top, 0.24 mm at sleeve base, and angular deviation is 1.5° (60).

2.5.4.2.9 Clinical factors

Several clinical factors lead to inaccuracy have been identified such as presence of debris in the drilled hole during implant placement

that preventing the implant from reaching its final position, resilience of mucosal tissues, improper fitting of the surgical guide and sleeve, limited mouth opening that reduced inter-arch clearance, and movement of the patient during surgery (16, 60).

2.4.3 Mental CAIS

There is a system that applies from static CAIS and conventional implant surgery. The DICOM file from CBCT scanning is imported into implant planning software where there are additional diagnostic and implant planning tools to enhance the process. Surgeon can visualizes the data, measures the distance, and selects appropriate size and suitable position of implant in the software program in 3D directions (14, 15, 55).

After planning, mesio-distal distance from adjacent teeth, bucco-lingual distance from bone edge to implant and apico-coronal distance from bone of to implant shoulder are determined and measured. The angulation of the implant fixture in relation to the adjacent clinical crown is also determined and measured. At surgical procedure, surgeon can visualize planned implant site directly on the computer screen in 3D; axial, coronal and sagittal view, together with some rough distance calculations.

In this system the implant is virtually planned in implant planning software program in 3D directions, however the 3D surgical guide does not prepare for the surgery (14, 15). The surgeon performs the implant bed preparation and implant placement in a free-hand manner (14, 15, 55, 63).

The disadvantage of this system is the surgeon unable to control implant angulation and depth during surgery. However, the advantages of this system over the conventional implant surgery is the implant is virtually planned in implant planning software before the surgical intervention resulting in it can compare the deviation of implant position between planned and placed dental implant.

2.5 Accuracy of implant position

The most common concern in implant surgery regarding CAIS is the accurately transfer of the virtual data for the planned implant position to the actual surgical procedure to place the implant and its final position intraorally. CAIS has often been recommended for implant placements in situations with a limited amount of bone or proximity to critical anatomical structures. Hence, it is importance to know the accuracy of this system (3).

Accuracy is defined as the deviation between planned and placed dental implant. There are many ways to investigate the deviation. The most often method is verified via preoperative and postoperative CBCT, through specific software that allow the matching of preoperative planning and postoperative placed implant positioning (64, 65).

In generally, the accuracy is investigated at three levels:

- Error at the entry point, measured at the center of the implant shoulder
- Error at the apex, measured at the center of the implant apex
- Angular deviation

Error at the entry and the apex are measured in millimeter (mm), while the angular deviation is measured in degrees (°). The error or deviation of these points is calculated in 3D, though several methods are used to describe the distance between the given points. The most common method is the actual distance measurement between the planned and placed point in 3D directions. By using a distinction between the deviation measured in the x, y, and z-axis and calculation from Pythagorean Theorem (Equation 1) (Fig 14-15) (3), where

- x = horizontal deviations in implant position in the mesio-distal direction
- y = horizontal deviations in implant position in the bucco-lingual direction
- z = vertical deviations in implant position in the apico-coronal direction

Equation 1 3D deviations using Pythagorean Theorem (3)

$$3Ddev = \sqrt{x^2 + y^2 + z^2}$$

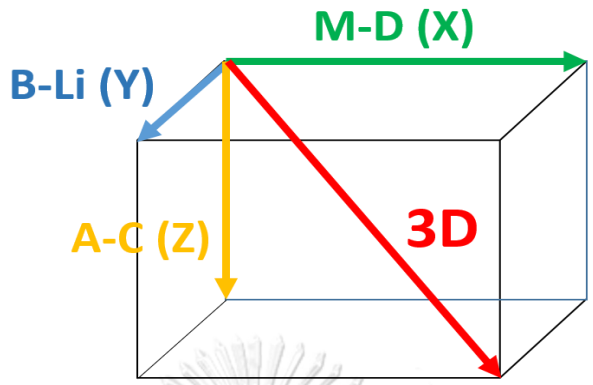


Figure 14 Deviation measured in x, y, z-axis

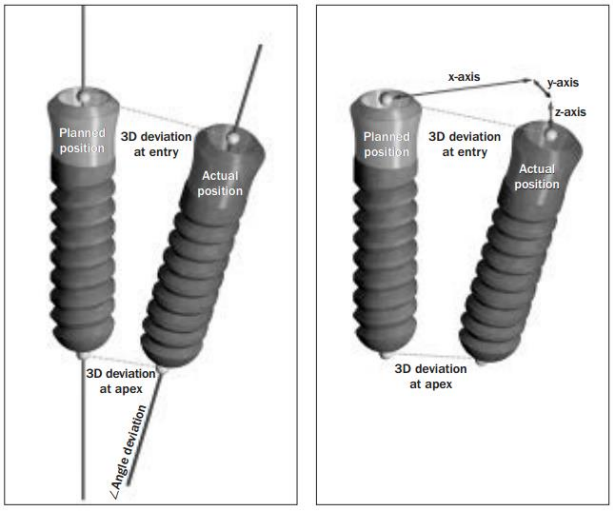


Figure 15 Illustration of different parameters for describing the deviations (Left) Different variables for describing deviations per implant illustrated (Right) Illustration of distinction between deviation measured in x, y, z-axis (3)

2.5.1 Accuracy of Mental CAIS

Alexander R. Edelmann et al., in 2016 (63) evaluated the accuracy of 18 single immediate implant placement. Before tooth extraction, the surgeon virtually planned implant positioning using preoperative CBCT data in SimPlant Pro 15 (Dentsply, Waltham, Mass). Appropriate mesio-distal, bucco-lingual dimensions from adjacent

teeth were determined and measured. The angulation of the implant fixture in relation to the adjacent clinical crown was also determined and measured. Surgery was performed follow planning in freehand technique. Accuracy was determined by using measurements the deviation between planned and placed implant position in the software using preoperative and postoperative CBCT scans. The mesio-distal dimensions (MI, DI) were determined and measured from the most cervical portion of the implant fixture to the plane of the adjacent teeth. The facio-lingual dimensions (LI) were determined and measured from the most lingual part of the adjacent teeth. The angulation of the implant fixture in relation to the clinical crown (IT) was also determined and measured. In the mesio-distal dimension, mean deviation is 0.02 mm slight distal and 0.02 mm slight mesial. In the facio-lingual dimension, mean deviation is 0.11 mm slight facial. For the angulation difference, there is a slight trend that the implant will flare a little facially 1.23°. However, no statistical difference between the planned and placed implant position in any measurement (Table 3).

Table 3 Deviation of implant position placed with mental CAIS

Study	Study design	Gap type	Implant number	Mean deviation (Min - Max)			
				IT Angle (°)	MI distance (mm)	DI distance (mm)	LI distance (mm)
Alexander RE et al 2016 (63)	Prospective	Immediate Single gap	18	1.23 (-1.59, 4.05)	-0.02 (-0.40, 0.37)	-0.02 (-0.42, 0.39)	-0.11 (-0.73, 0.50)

2.5.2 Accuracy of Static CAIS

Several reviews of scientific literature have been performed to evaluate the accuracy of stereolithographic surgical guide (Table 4).

Di Giacomo et al., in 2005 (66) evaluated the accuracy of 21 implants placed using SLA surgical guides generated from CT in 4 partially edentulous patients. Simplant software was used for virtual planning and comparing the deviation between planned and placed implants. The deviation was 1.45 ± 1.42 mm at the

implant shoulder, 2.99 ± 1.77 mm at the implant apex, and angular deviation of 7.25° ± 2.67°. They concluded that the stereolithographic surgical guides may be useful equipment in implant placement. However, the stability of surgical guide was important factor especially in cases of unilateral bone supported and non-tooth supported guides.

Ersoy et al., in 2008 (7) evaluated the accuracy of 94 implants placed using SLA surgical guides generated from CT. Stent Cad software program was used for planning implant position. SwissPlus software (Zimmer Dental, Carlsbad, CA) was used for comparing the CT images between planned and placed implants. The deviation in single tooth gap was 0.74 ± 0.40 mm at the implant shoulder, 1.66 ± 0.28 mm at the implant apex, and angular deviation of 3.71° ± 0.93°. The deviation in Kennedy class I and II was 1.23 ± 0.67 mm at the implant shoulder, 1.59 ± 0.74 mm at the implant apex, and angular deviation of 4.78° ± 1.86°. The deviation in fully edentulous area was 1.28 ± 0.92 mm at the implant shoulder, 1.6 ± 1.08 mm at the implant apex, and angular deviation of 5.1° ± 2.59°. The deviation was increasing with size of edentulous area. However, statistically significant differences in the deviation at the apex were observed between the single-tooth loss and partially edentulous groups and between single-tooth loss and fully edentulous groups. No significant differences were found among the other groups. They suggested that stereolithographic surgical guides were accurate tools for transferring ideal implant position from computer planning to the actual implant surgical phase of treatment and flapless implant surgery was possible with these guides.

Ozan et al., in 2009 (53) evaluated the accuracy of 110 implants placed using stereolithographic surgical guides. Stent Cad software program was used for planning the implant position while, 3D-software (Rhinoceros 4.0, McNeel Ins, Seattle, WA) was used for comparing the CT images between planned and placed implants. The deviation was 1.11 ± 0.7 mm at the implant shoulder, 1.41 ± 0.9 mm at the implant apex, and angular deviation of 4.1° ± 2.3°. They concluded that SLA surgical guide

using CT data was the reliable tool for implant placement both in flapless and open flap surgery.

Valente et al., in 2009 (67) evaluated the accuracy of 89 stereolithographic surgical guides generated from CT in 25 patients. The study was retrospective study. Simplant software program was used for comparing the CT images between planned and placed implants. The deviation was 1.4 ± 1.3 mm at the implant shoulder, 1.6 ± 1.2 mm at the implant apex, and angular deviation of 7.9° ± 4.7°. The survival rate of 96% with this method (mean follow-up, 36 months) and no major surgical complications were found.

Van Assche et al., in 2010 (68) evaluated the accuracy of implants placed by stereolithographic template in 8 partially edentulous patients. The surgery was done with flapless approach. Each patient required 2-4 implants. Radiographic data were obtained by CBCT or MSCT scan. Procera software was used for virtual planning implant. Nobel Guide software was used for comparing the CT images between planned and placed implants. The stereolithographic surgical guide was positioned on the remaining teeth and 1-2 anchor pins were inserted into the jawbone to stabilize the surgical guide during surgical intervention. The deviation was 0.6 ± 0.3mm at the implant shoulder, 0.9 ± 0.4 mm at the implant apex, and angular deviation of 2.21° ± 1.1°. They concluded that implants in partially edentulous can be placed with flapless approach via stereolithographic surgical guide with the acceptable deviations towards their planned position.

Pettersson et al., in 2012 (69) evaluated the accuracy of 139 implants placed with 25 stereolithographic surgical guides in fully edentulous jaws. The surgery was done in flapless approach. All stereolithographic surgical guides were mucosa supported guides. Procera software version 1.5 was used for virtual planning implant, while Nobel Guide software was used for comparing the deviation between planned and placed implants. The deviation was 0.8 mm (range 0.10-2.68) at the implant shoulder, 1.09 mm (range 0.24-3.62) at the implant apex, and angular deviation of

2.26° (range 0.24-11.74). No statistic differences were observed between maxilla and mandible.

Meta-analysis from Schneider et al., in 2009 (70) analyzed the accuracy of computer-guided template-based implant dentistry in 8 studies. One study was performed on model (50 implantation sites), four on cadavers (116 implantation sites) and three in humans (155 implant sites). One hundred fifty five implants were analyzed in 3 human clinical studies in 2003-2009 with 3 different implant planning software (SimPlant, SurgiGuide, and StentCAD) were used for comparing the deviation. In human, they reported the mean deviation at implant shoulder was 1.16 mm (95% CI: 0.92 to 1.39 mm), mean deviation at apex was 1.96 mm (95% CI: 1.33 to 2.58 mm), and angular deviation was 5.73° (95% CI: 3.95° to 7.49° (70). They reported that stereolithographic surgical guide was the reliable tools in implant placement.

Meta-analysis from Van Assche et al., in 2012 (5) that analyzed accuracy of 1326 implants with static computer-guided implant placement in 12 vivo studies. This study contained 10 different “static” computer-assisted implant sorftware (Ay-Design®, Aytasarim®, EasyTaxis®, SinterStationHiQ®, SurgiGuide®, Safe SurgiGuide®, SICAT®, Med3D®, NobelGuide®, Facilitate®). They reported that in vivo studies mean deviation at implant shoulder was 1.0 mm (95% CI: 0.7 to 1.3 mm), mean deviation at the apex was 1.4 mm (95% CI: 1.1 to 1.7 mm), and mean angular deviation 4.2° (95% CI: 3.6° to 5.0°) (5). However a comparison between 10 implant planning software was impossible because the heterogeneity in study designs. Moreover, they suggested that the stability of stereolithographic surgical guide was the crucial factor on the final accuracy of implant placement.

Table 4 Deviation of implant position placed with static CAIS

Study	Study design	Gap type	Implant number	Deviation (Mean ± SD)		
				Angle (°)	3D at implant shoulder (mm)	3D at implant apex (mm)
Di Giacomo et al 2005 (67)	Prospective	Partially edentulous	21	7.25±2.67	1.45±1.42	2.99±1.77
Ersoy et al 2008 (7)	In vivo	Single gap Kennedy Cl. I or II Fully edentulous	9 20 65	3.71 ± 0.93 4.78 ± 1.86 5.1 ± 2.59	0.74 ± 0.40 1.23 ± 0.67 1.28 ± 0.92	1.66 ± 0.28 1.59 ± 0.74 1.6 ± 1.08
Ozan et al 2009 (52)	Prospective	Partially edentulous	110	1.11 ± 0.7	1.41 ± 0.9	4.1 ± 2.3
Valente et al 2009 (53)	Retrospective	Partially edentulous Fully edentulous	89	7.9±4.7	1.4±1.3	1.6±1.2
Assche et al. 2010 (68)	Prospective	partially edentulous	19	2.2±1.1	0.6±0.3	0.9±0.4
Pettersson et al. 2012 (69)	Prospective	Fully edentulous	139	2.26	0.8	1.09
Assche et al 2012 (5)	Meta-analysis	Single gap Multiple gap Fully edentulous	990	3.81	0.99	1.24
Schneider et al 2009 (70)	Meta-analysis	Multiple gap Fully edentulous	155	5.26	1.07	1.63

2.5.3 Comparison of the accuracy between Static CAIS and Mental CAIS

There are many clinical studies that measured the accuracy of static CAIS in single missing tooth. However most of investigations due to the intrinsic nature of their study design were unable to determine whether the static CAIS was more accurate than the conventional implant surgery (65).

At present only one clinical randomized trial has compared the accuracy of static CAIS with mental CAIS in single missing tooth, the split-mouth design by Farley

et al., in 2013 (52). Each group contained 10 implants. All the implants were planned with the iDent Imagine software (iDent Imaging). After surgery the postoperative CBCT data was superimposed to preoperative CBCT data in Rapidform XOR/RESDESIGN (INUS Technology), volumetric or overlap differences were measure to compare the planned and placed implant position. They reported angle deviation, deviation at shoulder, deviation at apex were 3.68 ± 2.19°, 1.45 ± 0.60 mm, 1.82 ± 0.60 mm, respectively using static CAIS. For the mental CAIS, angle deviation, deviation at shoulder, deviation at apex were 6.13 ± 4.04°, 1.99 ± 1.00 mm, 2.54 ± 1.23 mm, respectively. The results showed that implants placed with static CAIS were closer to the planned positions in all dimensions, however statistically significant differences (P = 0.0409) were shown only at the implant shoulder, providing greater accuracy than implants placed with mental CAIS (Table 5) .

Vercruyssen M et al., in 2014 (14, 15) compared accuracy of implant placement between stereolithographic surgical guide (mucosa-/bone-supported) and mental CAIS in fully edentulous patients. Mimics® software (Materialise Dental) was used for comparing the deviation. An iterative closest point algorithm was used to match the jaws. The angular deviation, deviation at implant shoulder, deviation at implant apex of mucosa-supported stereolithographic surgical guide were 2.71 ± 1.36°, 1.38 ± 0.64 mm, and 1.60 ± 0.70 mm, respectively. The angular deviation, deviation at implant shoulder, deviation at implant apex of bone-supported stereolithographic surgical guide were 3.20 ± 2.70°, 1.33 ± 0.82 mm, and 1.50 ± 0.72 mm, respectively. The angular deviation, deviation at implant shoulder, deviation at implant apex of mental CAIS were 9.92 ± 6.01, 2.77 ± 1.54 mm, and 2.91 ± 1.52 mm, respectively. Based on types of stereolithographic surgical guide supported, no significant difference was found between mucosa and bone-supported. However, significant difference was found between static CAIS and mental CAIS. They concluded that inaccuracy of static CAIS was clearly less than in mental CAIS in all positions (Table 5).

There have been the in vitro study that compared the accuracy of the implant position between static static CAIS and mental CAIS. Sarment et al., in 2003 (71) compared the accuracy of implant position in 5 epoxy edentulous mandible with 5 surgeons. At the right side of jaw, 5 implants were placed by using conventional surgical guide while, on the left side of jaw, 5 implants were placed by using stereolithographic surgical guide. In static CAIS group, mean angle deviation, deviation at implant shoulder, mean deviation at implant apex were 8 ± 4.5°, 0.9 ± 0.5 mm, 1.0 ± 0.6 mm, respectively. In mental CAIS group, mean angle deviation, deviation at implant shoulder, mean deviation at implant apex were 4.5 ± 2°, 1.5 ± 0.7 mm, 2.1 ± 0.97 mm, respectively. The deviation of stereolithographic surgical guide less than conventional surgical guide in all dimensions. They concluded that stereolithographic surgical guide allow for improving the accuracy of implant placement (Table 5).

This results agree with the study from Nokar et al., in 2013 (72) that compared the accuracy of implant position in epoxy mandibles. Each group contained 32 implants in 8 mandibles. In static CAIS group, angular deviation was 1.2 ± 0.08°, deviation at implant shoulder was 0.88 ± 0.38 mm in mesio-distal direction, 0.22 ± 0.17 mm in bucco-lingual direction, and 0.11 ± 0.05 mm in apico-coronal direction. In mental CAIS group, angular deviation was 5.9 ± 4.5 °, deviation at implant shoulder was 2.4 ± 0.68 mm in mesio-distal direction, 0.39 ± 0.27 mm in bucco-lingual direction, and 0.7 ± 0.46 mm in apico-coronal direction. Implant placed with static CAIS has lower deviation than implant place with mental CAIS. They concluded that implant placement with stereolithographic surgical guide can improved the accuracy (Table 5).

Besides, there are the in vivo - in vitro studies that studied the accuracy between static CAIS and mental CAIS. The study from Nickenig et al., in 2010 (73) used coDiagnostiX implant software for planning and comparing the deviation of the implant position using CBCT data in unilateral free-end gap in the lower jaw. In static CAIS group, 23 implants were placed in lower jaws of 10 patients. In mental CAIS

group, manual implantation was performed in radiopaque anatomical casts of the same 10 patients who had undergone real implantation. After implantation, postoperative CBCT scans of master cast model with implant replicas of the definite prosthetic treatment together with the exact positioned template were superimposed onto the preoperative scans of the virtual planned implants. The results of static CAIS were mean angular deviation of 4.2 ± 3.04°, mean deviation at the implant shoulder in the mesio-distal direction of 0.9 ± 1.22 mm, bucco-lingual direction of 0.9 ± 1.06 mm, and mean deviation at the implant apex in the mesio-distal direction of 0.9 ± 0.94 mm, bucco-lingual direction of 0.6 ± 0.57 mm. While the results of mental CAIS were mean angular deviation of 9.8 ± 4.25°, mean deviation at the implant shoulder in the mesio-distal direction of 2.4 ± 1.91 mm, bucco-lingual direction of 3.5 ± 2.24 mm, and mean deviation at the implant apex in the mesio-distal direction of 2.0 ± 2.02 mm, bucco-lingual direction of 2.5 ± 2.48 mm. Static CAIS produced significantly smaller deviation than mental CAIS in all positions and accuracy of axis was also significantly improved (Table 5).

Table 5 Comparison the deviation of implant position placed with static and Mental CAIS

Table 5 Comparison the deviation of implant position placed with static CAIS and Mental CAIS

Study	Study design	Implant procedure	Gap type	Implant number	Deviation (Mean ± SD)								
					Angle (°)	Implant shoulder (mm)				Implant apex (mm)			
						3D	Mesiodistal	Buccolingual	Apicocoronal	3D	Mesiodistal	Buccolingual	Apicocoronal
Farley et al 2013 (52)	Prospective (split mouth)	Static CAIS	Single gap	10	3.68 ± 2.19	1.45 ± 0.60	N/A	N/A	1.2 ± 0.7	1.82 ± 0.60	N/A	N/A	1.24 ± 0.68
		Mental CAIS		10	6.13 ± 4.04	1.99 ± 1.00	N/A	N/A	1.51 ± 1.02	2.54 ± 1.23	N/A	N/A	1.59 ± 1.09
Vercruyssen M et al. 2014 (14)	Prospective	Static CAIS (Mucosa support)	Fully edentulous	52	2.71 ± 1.36	1.38 ± 0.64	N/A	N/A	N/A	1.60 ± 0.70	N/A	N/A	N/A
		Static CAIS (Bone support)		49	3.20 ± 2.70	1.33 ± 0.82	N/A	N/A	N/A	1.50 ± 0.72	N/A	N/A	N/A
		Mental CAIS		51	9.92 ± 6.01	2.77 ± 1.54	N/A	N/A	N/A	2.91 ± 1.52	N/A	N/A	N/A
Sarment et al 2003 (71)	In vitro	Static CAIS	Fully edentulous	25	8 ± 4.5	0.9 ± 0.5	N/A	N/A	N/A	1.0 ± 0.6	N/A	N/A	N/A
		Mental CAIS		25	4.5 ± 2	1.5 ± 0.7	N/A	N/A	N/A	2.1 ± 0.97	N/A	N/A	N/A
Nokar et al 2011 (72)	In vitro	Static CAIS	Multiple gap	32	1.2 ± 0.01	N/A	0.88 ± 0.38	0.22 ± 0.17	0.11 ± 0.05	N/A	N/A	N/A	N/A
		Mental CAIS		32	5.9 ± 4.5	N/A	2.4 ± 0.68	0.39 ± 0.27	0.7 ± 0.46	N/A	N/A	N/A	N/A
Nickenig et al 2010 (73)	In vivo	Static CAIS	Kennedy CLII	23	4.2 ± 3.04	N/A	0.9 ± 1.22	0.9 ± 1.06	N/A	N/A	0.9 ± 0.94	0.6 ± 0.57	N/A
	In vitro	Mental CAIS		23	9.8 ± 4.25	N/A	2.4 ± 1.91	3.5 ± 2.24	N/A	N/A	2.0 ± 2.02	2.5 ± 2.48	N/A

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Patients

3.1.1.1 Sample selection

Patients who need single tooth dental implants at the Faculty of Dentistry, Chulalongkorn University were invited to participate in the study.

Inclusion criteria:

- Single missing tooth space (Fig 16)
- Present mesial and distal neighboring teeth (Fig 16)
- Mesiodistal space ≥ 6.5 mm
- Mouth opening at least 30 mm
- Aged 20 years and over

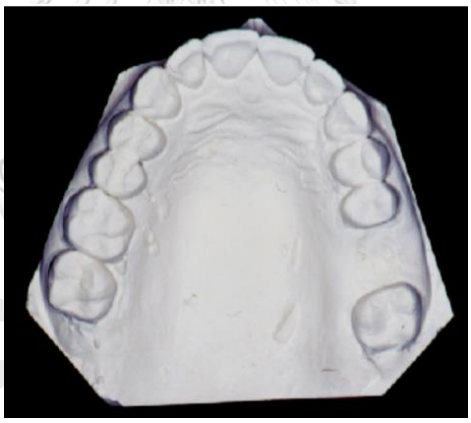


Figure 16 Single missing tooth space with mesial and distal teeth for supporting the surgical guide bilaterally

Exclusion criteria:

- Medically compromised subjects (ASA classification III-V)
- General contraindications against implant treatment (e.g. immunodeficiency, advanced systemic diseases)
- Clinical or radiographic sign presents any pathology in the jaw bone
- Heavy smoker ≥ 10 cigarettes/day

Withdrawal criteria

- Fracture or instability of surgical guide
- Subject chooses to exit study at any period of time

3.1.1.2 Sample size calculation

Sample size calculation was conducted via G*Power version 3.1.9.2 based on the report of Vercruyssen et al., in 2015 entitle "Computer-supported implant planning and guided surgery: a narrative review" (64) with significance level (α) of .05, power (1-β) of .95, and allocation ratio of 1. The required number of pairs was 27.

However, for losing the data at any period of time, the total sample size was used in this study is 60 subjects and divided into 2 groups, static CAIS and mental CAIS. Each group comprised of 30 implants.

3.1.2 Cone Beam Computed Tomography (CBCT) scanner

Accuitomo 3D machine (J. Morita Inc., Kyoto, Japan) for pre- and post-operation

120 kV, 5 mAs

FOV 100x100 mm, 140x100 mm (depend on patient's arch size)

Voxel size 125 μm

3.1.3 Surface scanner

Trios intraoral scanner (3shape, Copenhagen, Denmark) for intraoral scan

D900 model scanner (3shape, Copenhagen, Denmark) for model scan

3.1.4 Implant

Bone level implant (Straumann, institute Straumann AG, Basel, Switzerland).

Implant diameter 3.3, 4.1 or 4.8 mm and length 8, 10 or 12 mm.

3.1.5 Planning and accuracy analysis software

coDiagnostiX software version 9.7 (Dental Wings inc, Montreal, Canada)

3.2 Methods

This study was approved by ethic committee of Faculty of Dentistry, Chulalongkorn University (Study code: HREC-DCU 2017-062) and Thai Clinical Trials Registry (TCTR20181017002). Verbal and written consents were obtained from all subjects before attending this project.

All surgical procedure in mental CAIS group was operated by one experienced surgeons. Fifty two consecutive patients requiring 60 dental implants for replacement of single teeth were enrolled in the study. Each implant site was randomized into static or mental CAIS group by block randomization (5 implants per block).

3.2.1 Planning protocol

3.2.1.1 Static CAIS implant sites

All patients received a pre-operative Cone Beam Computer Tomography (CBCT) examination by Accuitomo 3D and an optical scan of the oral tissues by means of either Trios intraoral scanner or D900 model scanner. The Digital Imaging and Communications in Medicine (DICOM) file from the CBCT examination and the Standard Tessellation Language (STL) file from the optical scan were imported and merged in coDiagnostix® software version 9.7. The ideally virtual implant position was planned by one operator. Finally, the surgical guide with the embedded sleeve was designed and 3D printed with computer-aided design/computer-aided manufacturing (CAD/CAM) technology. All laboratory and 3D printing was performed by one standard dental lab.

3.2.1.2 Mental CAIS implant sites

Patients were taken an impression with irreversible hydrocolloid material and poured with stone for making a model. A wax up of the ideal prosthesis was conducted. A radiopaque stent was produced from the wax-up which the patients wore during the CBCT examination. The DICOM file from the CBCT examination was imported in coDiagnostix® software version 9.7. Virtual implant planning was performed by the same operator as in the Static CAIS

sites for all patients. Finally, a surgical stent was produced in conventional laboratory manner, allowing the surgeon to visualize the ideal prosthetic position intraoperatively. All conventional laboratory work was performed by the same dental lab.

3.2.2 Surgical protocol

All implants were placed by experienced surgeon under local anesthesia. The surgeon confirmed the virtual planning and drilling sequence prior to the surgery. All implants used in this study were bone level Straumann implants ranging in diameter from 3.3 - 4.8 mm and in length between 8 - 12 mm.

All implants were done under local anesthesia with reflection of full thickness mucoperiosteal flap.

In the mental CAIS, the implant bed preparations and implant insertion was performed in freehand manner. In static CAIS group, fit and stability of the surgical guide was verified prior to the surgery through tactile inspection and confirming fit through the respective window areas of the guide on top of teeth. Implant bed preparations and implant insertion were done through the surgical guide in accordance to the fully manufacturer's guided surgical protocol.

After the implant was in place, Resonance Frequency Analysis (RFA) and insertion torque were measured for all implants, and healing abutment was placed. All patients received postoperative instructions and appointment for suture removal. The postoperative medications administered included systemic antibiotics (amoxicillin 1 gram, twice a day) and analgesic (mefenamic acid 500 milligram, three times a day) for 5 days. In patients allergic to penicillin, clindamycin 300 milligram was administered three times a day.

3.2.3 Accuracy measurement

Postoperative CBCT data was taken by the same machine, Accuitomo 3D machine, with same protocol and superimposed with preoperative CBCT data using

automated surface best-fit matching with the iterative closest point algorithm in the treatment evaluation mode, coDiagnostix® software version 9.7. All measurements were done by one examiner, the same who conducted the virtual implant planning who was not the surgeon.

Steps for measuring the deviation in treatment evaluation mode of coDiagnostix® software version 9.7:

- Loaded postoperative CBCT data into program and clicked the Automatic Registration button
- Started surface registration by using the same hard tissue surface at least 3 points
- Manual aligned planned implant to placed implant with maximum enlarge image in 3 view; cross-sectional, tangential and 3D
- After aligned implant, the program calculated the mean differences of deviation from planned to placed implant position in 9 positions:
  - angle deviation in degrees (°)
  - deviation at implant shoulder in millimeters (mm)
    - 3D offset
    - mesio-distal direction
    - bucco-lingual direction
    - apico-coronal direction
  - deviation at implant apex in millimeters (mm)
    - 3D offset
    - mesio-distal direction
    - bucco-lingual direction
    - apico-coronal direction

3.2.4 Statistical analysis

Statistical analysis was carried out using IBM SPSS Statistics software (version 22 software SPSS Inc., Chicago, IL).

The distribution of data was tested by Kolmogorov-Smirnov Test. The result was non-normal distribution ($p = 0.2$).

Primary outcomes were mean differences of angle deviation, deviation at implant shoulder, and deviation at implant apex.

Mean differences of angle deviation, deviation at implant shoulder (3D/mesio-distal/bucco-lingual/apico-coronal direction) and deviation at implant apex (3D/mesio-distal/bucco-lingual/apico-coronal direction) between planned and placed implant position were compared between static and mental CAIS with Mann Whitney U test.

Mean differences of the deviation to each direction at implant shoulder and apex (mesial/distal/buccal/lingual/apical/coronal) between planned and placed implant position were compared between static and mental CAIS with Mann Whitney U test.

Patient demographic data and implant/site characteristics were compared between the two groups with a Chi-square test.

Multiple linear regression was utilized to investigate possible effect of type of arch (maxilla/mandible), location of implant (anterior/premolar/molar), side of arch (right/left), diameter and length of implant to the deviation in static and mental CAIS.

RFA and Mean insertion Torque measurements were compared between the two groups with Mann Whitney U test.

A calculated P value less than .05, representing the confidence interval of 95%, was considered statistically significant. The statistical power was analyzed by GPower software (Vercruyssen et al., 2015).

CHAPTER 4

RESULTS

A total of 52 patients received 60 implants as part of this study. Distribution of the implant sites and types are presented in Table 6.

Table 6 Distribution of implant in static and mental CAIS groups

Variables	Static CAIS (n = 30)	Mental CAIS (n = 30)	*P* value
Type of Arch			0.787
Maxilla	20	19	
Mandible	10	11	
Side of Arch			0.605
Right	15	17	
Left	15	13	
Implant Location			0.832
Anterior	5	5	
Premolar	9	7	
Molar	16	18	
Implant Diameter (mm)			0.766
3.3	6	4	
4.1	10	10	
4.8	14	16	
Implant Length (mm)			0.866
8	9	10	
10	17	15	
12	4	5	

The deviation between planned and final implant position for the two groups is presented in Table 7. Mean angle deviation, deviation at shoulder and apex in static CAIS group were 3.1 ± 2.3°, 1.0 ± 0.6 mm and 1.3 ± 0.6 mm, respectively. In the mental CAIS group, mean angle deviation, deviation at shoulder and apex were 6.9 ± 4.4°, 1.5 ± 0.7 mm and 2.1 ± 1.0 mm, respectively. Static CAIS technique showed less deviation than mental CAIS in all measurements. However, statistically significant

differences between the two techniques were found between six out of nine parameters of the measured deviation:

a) angle deviation,

b) 3D, mesio-distal and apico-coronal deviation at implant shoulder

c) 3D, mesio-distal deviation at implant apex

Table 7 Deviation of implant position in static and mental CAIS groups

	Static CAIS (n = 30)		Mental CAIS (n = 30)		P value
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	
Angle deviation (°)	3.1 ± 2.3	0.00 - 8.60	6.9 ± 4.4	0.50 - 16.90	0.001*
Deviation at implant shoulder (mm)					
3D	1.0 ± 0.6	0.20 - 2.67	1.5 ± 0.7	0.39 - 4.03	0.001*
Mesio-Distal	0.3 ± 0.3	0.03 - 0.95	0.6 ± 0.4	0.03 - 1.67	0.001*
Bucco-Lingual	0.4 ± 0.4	0.00 - 1.65	0.5 ± 0.5	0.00 - 2.14	0.162
Apico-Coronal	0.7 ± 0.6	0.05 - 2.09	1.0 ± 0.8	0.03 - 3.95	0.043*
Deviation at implant apex (mm)					
3D	1.3 ± 0.6	0.24 - 2.57	2.1 ± 1.0	0.61 - 4.53	0.001*
Mesio-Distal	0.6 ± 0.5	0.02 - 1.56	1.2 ± 0.8	0.03 - 3.04	0.001*
Bucco-Lingual	0.7 ± 0.5	0.00 - 2.12	1.0 ± 0.9	0.02 - 3.19	0.379
Apico-Coronal	0.7 ± 0.6	0.05 - 2.14	1.0 ± 0.8	0.03 - 3.71	0.104

Type of arch, side of arch, location of implant, diameter and length of the implant were not affected to angle deviation and deviation at implant shoulder and apex for either static or mental CAIS ($p > 0.05$) is presented in table 8.

The scattering plot of the mean deviation (mesio-distal, bucco-lingual and apico-coronal) for both implant shoulder and apex of each implant is shown in Fig 17. At the implant shoulder, statistically significant differences between the two techniques were found at mesial, distal and apical direction. At the implant apex, statistically significant differences between the two techniques were found at distal and buccal direction.

Table 8 Possible effect of type of arch, side of arch, location of implant, and size of implant to the deviation in static and mental CAIS (p value)

Variables	*p* value					
	Angle deviation		Deviation at implant shoulder		Deviation at implant apex	
	Static	Mental	Static	Mental	Static	Mental
Type of Arch	0.261	0.366	0.069	0.218	0.137	0.696
Side of Arch	0.117	0.299	0.137	0.422	0.102	0.739
Implant Location	0.544	0.971	0.140	0.547	0.521	0.781
Implant Diameter	0.584	0.429	0.403	0.594	0.470	0.810
Implant Length	0.933	0.412	0.250	0.154	0.521	0.097

The primary stability of dental implants measured through RFA in static CAIS group was a mean 63.63 for the buccal side and 63.70 for the mesial side respectively. In the mental CAIS group the mean was for buccal side 70.67 and for mesial side was 71.17.

Mean insertion Torque in static CAIS group was 23.17 Ncm while in mental CAIS was 28.67 Ncm. Both differences were statistically significant (RFA buccal p=0.002, mesial p=0.001, Torque value p=0.013.

The analysis from GPower indicated that the power of the study was 0.95, when the alpha level probability was set at 0.05.

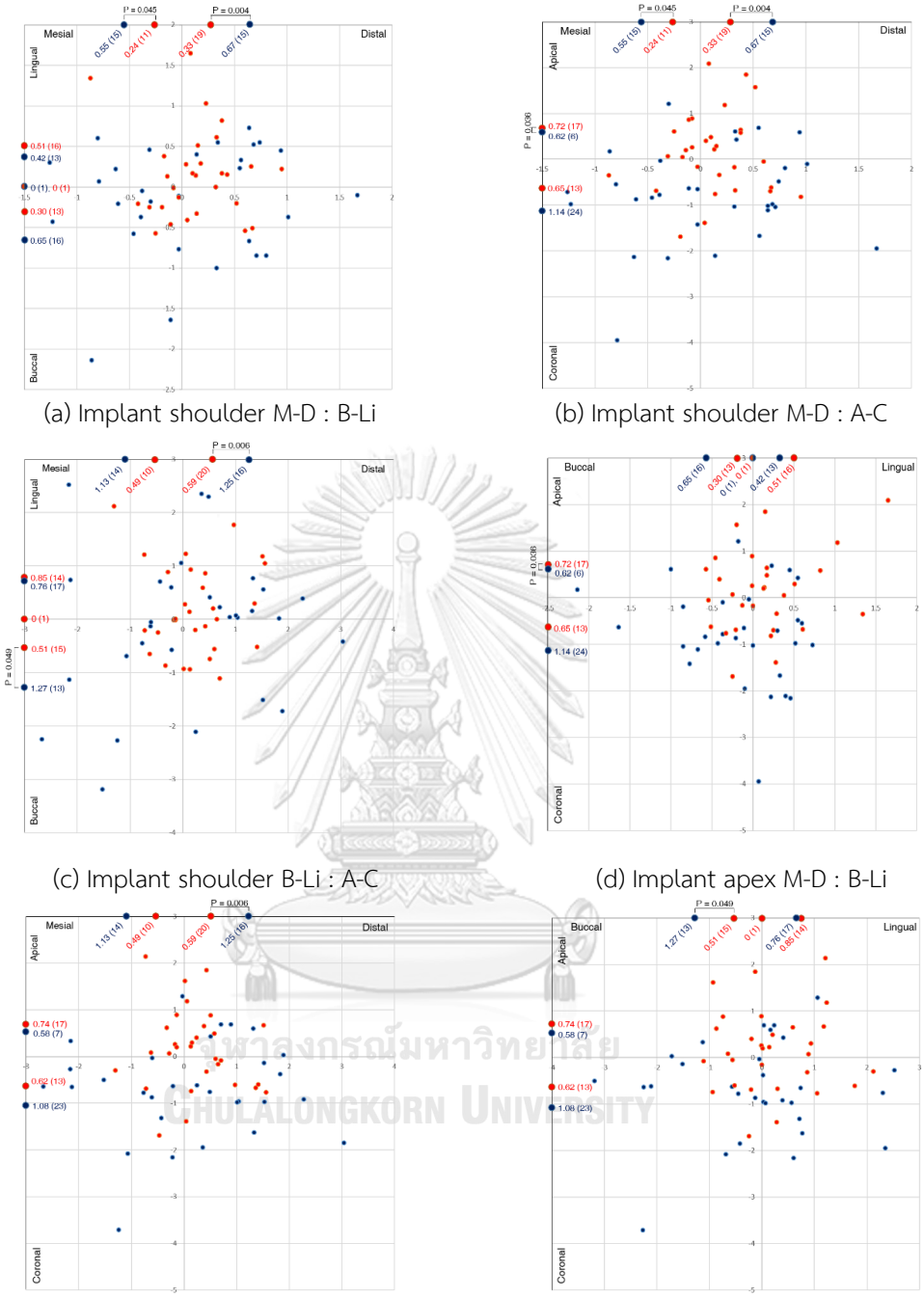


Figure 17 The scattering plot of the mean deviation (mesio-distal, bucco-lingual and apico-coronal) for both implant shoulder and apex of each implant

Mean deviation (Case) Blue dot : mental CAIS group, Red dot : static CAIS group

At implant shoulder, statistical different were found between static and mental CAIS groups at mesial, distal and apical direction, At implant apex, statistical different were found between static and mental CAIS groups at distal and buccal direction

CHAPTER 5

DISCUSSION

The present studied showed significantly higher accuracy of implants placed with static CAIS in 6 out of the 9 studied deviation parameters; angle deviation, 3D deviation at implant shoulder, mesio-distal deviation at implant shoulder, apico-coronal deviation at implant shoulder, 3D deviation at implant apex, mesio-distal deviation at implant apex. Mean angle deviation, 3D deviation at shoulder and apex in static CAIS group were 3.1 ± 2.3°, 1.0 ± 0.6 mm and 1.3 ± 0.6 mm, respectively. . In the mental CAIS group, mean angle deviation, 3D deviation at shoulder and apex were 6.9 ± 4.4°, 1.5 ± 0.7 mm and 2.1 ± 1.0 mm, respectively.

The results of the present study come in agreement with that reported in a split-mouth study by Farley et al., in 2013 (18), however, the sample was limited to 10 implants in each group. They reported angle deviation, deviation at shoulder, deviation at apex were 3.7 ± 2.2°, 1.5 ± 0.6 mm, 1.8 ± 0.6 mm, respectively using static CAIS. For the conventional group, angle deviation, deviation at shoulder, deviation at apex were 6.1 ± 4.0°, 2.0 ± 1.0 mm, 2.5 ± 1.2 mm, respectively. Implants placed with static CAIS were closer to the planned position in all dimensions than the conventional placement. However, significant differences were only found in the horizontal deviation of the implant shoulder. The authors further reported a limitation of the study being the fit of the CAD/CAM guides, some of which needed relining with clear acrylic resin in order to enhance stability prior to the surgery.

Vercruyssen M et al., in 2014 (14, 15) compared accuracy of implant placement between stereolithographic surgical guide (mucosa-/bone-supported) and mental CAIS in fully edentulous patients. The angular deviation, deviation at implant shoulder and apex of mucosa-supported stereolithographic surgical guide were 2.71 ± 1.36°, 1.38 ± 0.64 mm, and 1.60 ± 0.70 mm, respectively. The angular deviation, deviation at implant shoulder and apex of bone-supported stereolithographic surgical guide were 3.20 ± 2.70°, 1.33 ± 0.82 mm, and 1.50 ± 0.72 mm, respectively. The

angular deviation, deviation at implant shoulder, deviation at implant apex of mental CAIS were 9.92 ± 6.01, 2.77 ± 1.54 mm, and 2.91 ± 1.52 mm, respectively. The deviation of stereolithographic surgical guide less than mental CAIS. The results of this study in static CAIS closed with the results from Vercruyssen M et al., in 2014 but the deviation of mental CAIS less than the fully edentulous study. This results explain by in static CAIS, the implant surgery was controlled by metal sleeve embedded in 3D printed surgical stent, while in mental CAIS, implant surgery was controlled by the surgeon. For mental CAIS, the accuracy of single tooth gap surgery in this study more than fully edentulous study from Vercruyssen M et al., in 2014. This explain by in fully edentulous, there is no reference for controlling the position of implant, while in single tooth gap, neighboring teeth can be the reference during surgical intervention.

Most other reported comparative studies on the accuracy of implant position performed by static CAIS and freehand technique are conducted in-vitro. Sarment et al., in 2003 (71) and Nokar et al., in 2011 (71, 72) reported that the deviation of CAD/CAM surgical guide less than conventional surgical guide in all dimensions. These results were agreement with the combined in vivo - in vitro study from Nickenig et al., in 2010 (74).

The deviation of static CAIS in this report come in agreement with the meta-analysis from Assche et al., in 2012 (5), they revealed mean angle deviation was 3.8° (0-24.9°), mean deviation at implant shoulder and implant apex were 1.0 mm (ranging from 0-6.5 mm) and 1.2 mm (ranging from 0-6.9 mm). While meta-analysis from Schneider et al., in 2009 (20) reported more deviate than this study. They reported mean angle deviation was 5.3° (95% CI: 4.0-6.6°), mean deviation at implant shoulder was 1.1 mm (95% CI: 0.9-1.4 mm) and mean deviation at implant apex was 1.6 mm (95% CI: 1.3-2.0 mm). Nevertheless, both of these reviews have included in-vivo and in-vitro studies, addressing single and multiple missing teeth, thus affecting the ability to directly extrapolate into more specific clinical settings.

The angle deviation of mental CAIS in this study is more deviate than the study from Alexander RE et al., in 2016 (63) but that study is limited only in single immediate implant surgery at anterior tooth and premolar. This study come in agreement with the study from Choi et al., in 2017 (45), they concluded that one of the factors that influencing to the deviation of implant position was timing of implant placement. The immediate placement was significantly more accurate than the delayed placement.

Behneke et al., in 2012 (17) concluded that increase in the number of sleeve-guided site preparation steps made a higher accuracy, hence implant placement through the guide allowed a more accurate than freehand insertion or freehand drilling. No significant differences were found for the linear deviation at the coronal or the angular deviation between implants placed in maxilla and mandible. This study agrees with the study from Behneke et al., in 2012. Implant placement with static CAIS was more accurate than the mental CAIS and no significant differences were found between maxilla and mandible.

In this study, the results were come in agree with the results from D' Hease et al., in 2012 that posterior implants were more deviate than anterior implants. However, no significant differences were found. There was no influence of the length of implant in this study. In contrast, Length of implant in the study of D' Hease et al., in 2012 had influence to the deviation. However, in this study, the length of implant limited to 8-12 mm but in the study of D' Hease et al., in 2012, implant length was 8-15 mm.

The deviation of implant position in this study was not affected by side of arch (maxilla/mandible) and implant diameter. The data was similar to the study from Choi et al., in 2017 (45). However, there was not the reliable study because they measured the deviation by using preoperative CBCT merging with the postoperative periapical film and measured it with two dimensional aspect.

Albeit there is a body of evidence suggesting in general higher accuracy of implants placed through static CAIS, limitations of this technique include higher costs and need for favorable anatomic conditions in terms of mouth opening (12, 16, 45).

It was an interesting finding that implants placed with static CAIS had significantly lower primary stability, measured both by RFA and mean insertion torque. In the static CAIS protocol the implant is fully inserted via the 3D surgical guide, allowing for controlling of the vertical depth only indirectly through the markings of the guide template. At the same time, the operator has very little tactile perception of the implant stability other than the torque value. When the implant reaches the predetermined vertical position, regardless of the extent of stability the guide was removed and insertion torque and RFA were measured. On the contrary, in the mental CAIS the operator has direct vision of the bone level and the vertical implant position and could possibly determine the depth in response to the tactile perception of primary stability, possibly sinking slightly more the implant in the bone if required. This might explain why the RFA measurements as well as the torque value were consistently lower for the static CAIS group in this study. In all cases however there was enough clinical stability and no problems were noted.

Within the limitations of the present investigation, it was concluded that the use of static CAIS will result in significantly higher accuracy of implant placement than mental CAIS in a single tooth space. Unfortunately, this study focused on the accuracy of implant position, thus the other factors such as cost effectiveness, duration of the surgical intervention, and patient reported outcome were suggest for further research. Future research could also address more complex surgical scenario such as replacement of multiple missing teeth, immediate implant placement, flapless/open flap design or experience of the surgeon. Moreover, the reduction of surgical time and cost effectiveness should be taken in further study.

CHAPTER 6

CONCLUSION

Within the limitation of the study, the use of static CAIS demonstrated higher accuracy of implant positioning compared to the mental CAIS in single tooth gap.

APPENDIX

APPENDIX A

Informed consent, Consent form, Withdrawal form

เอกสารข้อมูลคำอธิบายสำหรับอาสาสมัครที่เข้าร่วมในการวิจัย

(Patient/Participant Information Sheet)

1. ชื่อโครงการ (ไทย) การศึกษาเปรียบเทียบความแม่นยำของการฝังรากฟันเทียมชี่เดี่ยวระหว่างการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำ

   ชื่อโครงการ (อังกฤษ) COMPARATIVE STUDY OF THE ACCURACY OF SINGLE TOOTH IMPLANTS PLACED BETWEEN STATIC AND MENTAL COMPUTER ASSISTED SURGERY

2. ชื่อผู้วิจัยหลัก ทพญ.ปาลิตา สมิตกาญจน์

   ชื่อผู้วิจัยร่วม ผศ.ทพญ.ดร.เกศกัญญา สัพพะเลข

   สถาบันที่สังกัด ภาควิชาศัลยศาสตร์ คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

   อาจารย์ที่ปรึกษา รศ.ทพ.ดร.อาทิพันธุ์ พิมพ์ขาวขำ

   แหล่งทุนวิจัย ทุน 90 ปีจุฬาลงกรณ์มหาวิทยาลัย

3. วัตถุประสงค์ของโครงการ เพื่อเปรียบเทียบความแม่นยำของวิธีการผ่าตัดที่มีผลต่อตำแหน่งของการฝังรากฟันเทียมระหว่างการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำ

4. สถานที่ดำเนินการวิจัย ภาควิชาศัลยศาสตร์ คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

5. วิธีการที่เกี่ยวข้องกับการวิจัย

   หากท่านมีความประสงค์เข้าร่วมในโครงการวิจัย ท่านจะต้องได้รับการตรวจช่องปากจากทันตแพทย์และถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีม เพื่อประเมินว่าท่านมีคุณสมบัติตรงตามเกณฑ์ที่กำหนด และมีกระดูกเพียงพอในการฝังรากเทียมได้ จากนั้นท่านจะถูกสุ่มเข้ากลุ่มวิจัยกลุ่มใดกลุ่มหนึ่ง เพื่อวางแผนการรักษาสำหรับการใส่ฟันเทียมและการผ่าตัดฝังรากฟันเทียม รวมทั้งออกแบบแผ่นจำลองนำทางผ่าตัด

   (กลุ่มการวิจัยแบ่งออกเป็น 2 กลุ่ม ได้แก่ การผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิต คือวิธีการผ่าตัดฝังรากฟันเทียมผ่านแผ่นจำลองนำทางผ่าตัดที่ออกแบบผ่านโปรแกรมจำลองการผ่าตัดฝังรากฟันเทียม โดยที่แผ่นจำลองนำทางผ่าตัดจะเป็นตัวควบคุมมุม

และความลึกของการฝังรากฟันเทียม จะไม่สามารถเปลี่ยนตำแหน่งในการฝังรากฟันเทียมได้ ทั้งนี้แผ่นจำลองนำทางผ่าตัดที่ผลิตขึ้นมานั้นใช้วัสดุที่ไม่เป็นอันตรายต่อร่างกาย

ส่วนการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือผ่านการจดจำ คือ วิธีการผ่าตัดฝังรากฟันเทียมที่ผ่านการออกแบบตำแหน่งรากฟันเทียมผ่านโปรแกรมจำลองการผ่าตัดฝังรากฟันเทียม โดยที่ไม่มีการผลิตแผ่นจำลองนำทางผ่าตัดขึ้นมา ทันตแพทย์จะเป็นผู้ควบคุมมุมและความลึกของการฝังรากฟันเทียมโดยตรงให้เป็นไปตามที่ได้วางแผนไว้ ซึ่งการฝังรากฟันเทียมทั้ง 2 วิธี เป็นวิธีที่เป็นมาตรฐานของการรักษา ได้รับการยอมรับโดยทั่วไป)

กลุ่มการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิต จะดำเนินการผ่าตัดโดยรศ.ทพ.ดร.อาทิพันธุ์ พิมพ์ขาวขำ และผศ.ทพญ.ดร.เกศกัญญา สัพพะเลข หรือนิสิตหลังปริญญาที่อยู่ในการควบคุมและวางแผนการรักษาจากอาจารย์ทั้ง 2 ท่าน ส่วนในกลุ่มการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือผ่านการจดจำ จะดำเนินการผ่าตัดโดยทันตแพทย์ผู้มีประสบการณ์การผ่าตัดฝังรากฟันเทียมจำนวน 2 ท่าน (รศ.ทพ.ดร.อาทิพันธุ์ พิมพ์ขาวขำ และผศ.ทพญ.ดร.เกศกัญญา สัพพะเลข) โดยทันตแพทย์ผู้ทำการผ่าตัดจะผ่านการทำสหสัมพันธ์ภายในชั้น (Intraclass Correlation Coefficient) เพื่อวัดความน่าเชื่อถือระหว่างผู้ทำการผ่าตัด

ในวันที่ท่านมารับการผ่าตัดฝังรากฟันเทียม ท่านจะได้รับการรักษาด้วยวิธีมาตรฐานสำหรับการผ่าตัดฝังรากฟันเทียมโดยทั่วไป โดยจะมีการฉีดยาชาเฉพาะที่ เปิดเหงือก กรอกระดูกเพื่อเป็นที่อยู่ของรากฟันเทียม ฝังรากฟันเทียมลงในเบ้ากระดูก วัดเสถียรภาพของรากฟันเทียม และเย็บปิดปากแผล

หลังจากผ่าตัดฝังรากฟันเทียมประมาณ 2 สัปดาห์ จะนัดท่านกลับมาเพื่อตรวจแผลผ่าตัดและทำการตัดไหม

1 เดือนหลังการผ่าตัดฝังรากฟันเทียม จะตรวจแผลผ่าตัด ถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีม และวัดเสถียรภาพของรากฟันเทียม

3 เดือนหลังการผ่าตัดฝังรากฟันเทียม จะทำการประเมินอัตราสำเร็จของรากฟันเทียมจากทางคลินิกและภาพรังสี และวัดเสถียรภาพของรากฟันเทียม หากผลการตรวจและการวัดเสถียรภาพเป็นที่น่าพอใจ (ค่าเสถียรภาพมากกว่า 60) ทันตแพทย์จะพิมพ์ปากเพื่อเตรียมทำฟันเทียม และดำเนินการตามขั้นตอนของการใส่ฟันจนท่านได้ฟันเทียมยึดติดบนรากฟันเทียมเรียบร้อยโดยใช้เวลาประมาณ 1-1.5 เดือน หลังจากนี้ ในเดือนที่ 5 หลังการผ่าตัดฝังรากฟัน

เทียมท่านจะได้รับการนัดกลับมาเพื่อทำการประเมินอัตราสำเร็จของรากฟันเทียมจากทางคลินิกและภาพรังสีอีกครั้งก่อนสิ้นสุดโครงการ

ในรายที่ค่าเสถียรภาพของรากฟันเทียมน้อยกว่า 60 หรือมีความผิดปกติใดๆเกิดขึ้นกับบริเวณที่ทำการฝังรากฟันเทียม ผู้วิจัยจะทำการแก้ไขความผิดปกตินั้น และรอให้มีการหายของแผลต่ออีก 2 เดือน และจะทำการประเมินอัตราสำเร็จของรากฟันเทียมจากทางคลินิกและภาพรังสี และวัดเสถียรภาพของรากฟันเทียมอีกครั้ง โดยในครั้งนี้ หากผลการตรวจและการวัดเสถียรภาพเป็นที่น่าพอใจ (ค่าเสถียรภาพมากกว่า 60) ทันตแพทย์จะพิมพ์ปากเพื่อเตรียมทำฟันเทียม และดำเนินการตามขั้นตอนของการใส่ฟันจนท่านได้ฟันเทียมเช่นกัน แต่หากผลตรวจยังไม่เป็นที่น่าพอใจ (ค่าเสถียรภาพยังคงน้อยกว่า 60) ทันตแพทย์จะดำเนินการถอนรากฟันเทียมออกและเป็นอันสิ้นสุดโครงการวิจัย

หากท่านยังมีความประสงค์จะผ่าตัดฝังรากเทียมใหม่หลังจากที่แผลถอนรากฟันเทียมหายดีแล้ว (ในรายที่รากฟันเทียมมีการโยก หลุด หรือต้องถอนออกภายใน 5 เดือน นับตั้งแต่วันที่ผ่าตัดฝังรากฟันเทียม) โดยที่ลักษณะกระดูกของท่านยังมีเหมาะสมสำหรับการฝังรากฟันเทียม ทันตแพทย์จะดำเนินการอย่างเหมาะสมเพื่อให้ท่านได้รับการฝังรากเทียมใหม่โดยไม่เสียค่าใช้จ่ายในการผ่าตัดฝังรากฟันเทียม ค่ารากฟันเทียม ค่ากระดูกเทียมและอุปกรณ์ส่วนต่อ แต่ท่านจะมีค่าใช้จ่ายในการทำฟันเทียม และค่าถ่ายภาพรังสี

หากท่านไม่ประสงค์จะผ่าตัดฝังรากเทียมใหม่หรือลักษณะกระดูกของท่านไม่เหมาะสมที่จะฝังรากฟันเทียม ทันตแพทย์จะให้คำแนะนำเพื่อให้ท่านได้รับการใส่ฟันที่เหมาะสม โดยท่านจะมีค่าใช้จ่ายในการทำฟันเทียม

หลังจากสิ้นสุดโครงการวิจัยแล้ว ทันตแพทย์ผู้ทำการวิจัยจะนัดท่านกลับมาตรวจและติดตามผลการรักษาอย่างต่อเนื่อง

หากท่านยินดีเข้าร่วมในโครงการวิจัย ผู้วิจัยจะปฏิบัติต่อท่านเป็นขั้นตอนดังแสดงในตาราง

ครั้งที่	เวลา	รายละอียด
1	-	ซักประวัติ ตรวจในช่องปาก พิมพ์ปาก เตรียมสภาพช่องปาก ถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีม
2	วันที่ 1	ผ่าตัดฝังรากฟันเทียมลงกระดูกขากรรไกร วัดเสถียรภาพของรากฟันเทียม

3	2 สัปดาห์หลังผ่าตัด	ตรวจแผลผ่าตัด ตัดไหม
4	1 เดือนหลังผ่าตัด	ตรวจแผลผ่าตัด ถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีม วัดเสถียรภาพของรากฟันเทียม
5	3 เดือนหลังผ่าตัด	ประเมินอัตราสำเร็จของรากฟันเทียม ถ่ายภาพรังสี วัดเสถียรภาพของรากฟันเทียม พิมพ์ปากเพื่อทำฟันเทียมและดำเนินการจนท่านได้รับฟันเทียมโดยใช้เวลาประมาณ 1-1.5 เดือน (เฉพาะในรายที่ค่าเสถียรถาพของรากฟันเทียมมากกว่า 60 และไม่มีความผิดปกติหรือภาวะแทรกซ้อนเกิดขึ้นกับบริเวณที่ทำการฝังรากฟันเทียม) แต่หากค่าเสถียรภาพของรากฟันเทียมน้อยกว่า 60 หรือมีความผิดปกติใดๆเกิดขึ้นกับบริเวณที่ทำการฝังรากฟันเทียม ผู้วิจัยจะทำการแก้ไขความผิดปกตินั้น และรอให้มีการหายของแผลต่ออีก 2 เดือน
6	5 เดือนหลังผ่าตัด	ในรายที่ได้รับการทำฟันเทียมที่ 3 เดือน - ประเมินอัตราสำเร็จของรากฟันเทียม ถ่ายภาพรังสี ในรายที่ยังไม่ได้รับการทำฟันเทียมที่ 3 เดือน - วัดเสถียรภาพของรากฟันเทียม ถ่ายภาพรังสี - พิมพ์ปากเพื่อทำฟันเทียมและดำเนินการจนท่านได้รับฟันเทียมโดยใช้เวลาประมาณ 1-1.5 เดือน (เฉพาะในรายค่าเสถียรภาพของรากฟันเทียมมากกว่า 60 และไม่มีความผิดปกติหรือภาวะแทรกซ้อนเกิดขึ้นกับบริเวณที่ทำการฝังรากฟันเทียม) - แต่หากค่าเสถียรภาพของรากฟันเทียมน้อยกว่า 60 หรือมีความผิดปกติใดๆเกิดขึ้นกับบริเวณที่ทำการฝังรากฟันเทียม ผู้วิจัยจะทำการถอนรากฟันเทียมออก

6. เหตุผลที่เชิญเข้าร่วมเป็นอาสาสมัครในโครงการ

ท่านได้รับเชิญเข้าร่วมการศึกษาวิจัย เนื่องจากท่านเป็นอาสาสมัครที่มีสุขภาพดี โดยท่านจะได้อ่านข้อมูลที่เกี่ยวข้องกับโครงการนี้ก่อน ถ้าท่านมีข้อสงสัยใดๆเกี่ยวกับการศึกษาวิจัยนี้

สามารถซักถามผู้วิจัยได้ หากท่านตัดสินใจเข้าร่วมการศึกษาวิจัย ท่านจะได้รับสำเนาใบยินยอมที่ท่านเซ็นชื่อกำกับเก็บไว้ 1 ฉบับ

คุณสมบัติของผู้เข้าร่วมการวิจัยสามารถสรุปได้ดังต่อไปนี้

1. สูญเสียฟันกลายเป็นสันเหงือกว่างขนาดเทียบเท่ากับฟัน 1 ซี่ 1 ช่องว่าง ที่ไม่ใช่ซี่หลังสุดของขากรรไกร และต้องการทำรากฟันเทียมเพื่อบูรณะฟันที่สูญเสียไป (กรณีที่มีช่องว่างมากกว่า 1 ช่อง จะไม่ถือว่าอยู่ในกลุ่มวิจัย)
2. สามารถอ้าปากได้กว้างปกติ เพียงพอต่อการวางแผ่นจำลองนำทางผ่าตัดโดยไม่น้อยกว่า 3 เซนติเมตร
3. อายุมากกว่า 20 ปี
4. มีสุขภาพดี(ทั้งทางร่างกายและจิตใจ)
5. ไม่มีพยาธิสภาพบริเวณที่จะฝังรากฟันเทียม
6. สูบบุหรี่น้อยกว่า 10 มวนต่อวัน
7. สามารถเข้าร่วมการวิจัยได้ตลอดโครงการ

7. ความรับผิดชอบของอาสาสมัครและระยะเวลาที่อาสาสมัครจะอยู่ในโครงการ

ขอให้ท่านปฏิบัติตามที่ผู้วิจัยแนะนำในระหว่างที่ท่านเข้าร่วมโครงการวิจัยนี้ โดยระยะเวลาที่ท่านจะอยู่ในโครงการนี้คือ 5 เดือนนับตั้งแต่วันที่ทำการผ่าตัดฝังรากฟันเทียม

8. ประโยชน์ของการวิจัยที่อาสาสมัครและ/หรือผู้อื่นที่อาจได้รับ

1. ท่านจะได้ใส่ฟันเทียมชนิดติดแน่นและรากฟันเทียมที่มีตำแหน่งแม่นยำใกล้เคียงกับแผนการรักษา เพื่อทดแทนฟันที่สูญเสียไป เสริมให้ท่านมีคุณภาพชีวิตที่ดีขึ้น

2. ผลการวิจัยของท่านจะได้ข้อมูลความแม่นยำของการฝังรากฟันเทียมหนึ่งซี่ระหว่างการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำ ซึ่งจะช่วยในการตัดสินใจเลือกวิธีการรักษาของทันตแพทย์ที่มีต่อการผ่าตัดฝังรากฟันเทียมโดยใช้คอมพิวเตอร์ช่วยเหลือ

9. ความเสี่ยงหรือความไม่สะดวกที่อาจจะเกิดขึ้นแก่อาสาสมัคร และในบางกรณีแก่ทารกในครรภ์หรือทารกที่ดื่มนมมารดา

การฝังรากฟันเทียมของท่านมีโอกาสประสบความล้มเหลวอันเป็นภาวะแทรกซ้อนของการรักษาที่เกิดขึ้นได้ และอาจเสี่ยงต่อการเกิดผลแทรกซ้อนจากการผ่าตัด ซึ่งเหมือนกับการผ่าตัดในช่องปากโดยทั่วไป เช่น อาการปวด บวม หรืออาจติดเชื้อบริเวณแผลภายหลังการผ่าตัด แต่ขอให้ท่านปฏิบัติตามที่ผู้วิจัยแนะนำ ทั้งนี้ผู้วิจัยตระหนักถึงผลแทรกซ้อนต่างๆ ที่อาจเกิดขึ้น และมีมาตรการในการลดความเสี่ยงเหล่านี้ โดยกระทำการรักษาตามมาตรฐานของวิชาชีพอย่างเคร่งครัด

10. ค่าใช้จ่ายที่อาสาสมัครจะต้องจ่าย หรืออาจจะต้องจ่าย

อาสาสมัครจะมีค่าใช้จ่ายในการผ่าตัดฝังรากฟันเทียมและค่าทำฟันเทียมตามปกติ โดยราคาขึ้นอยู่กับจำนวนซี่ฟันที่ใส่ ตามอัตราที่กำหนดไว้โดยคณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ค่าถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีมเพื่อวางแผนการรักษา (3,000 บาทต่อภาพ) ค่าพิมพ์ฟันและแบบจำลองฟันเพื่อวางแผนการรักษา (ประมาณ 1,000 บาท) ค่าฝังรากฟันเทียมและทำครอบฟัน (35,000-70,000 บาท)

ค่าแผ่นจำลองนำทางผ่าตัด ค่าสแกนแบบจำลองฟัน ค่าโปรแกรมคอมพิวเตอร์ช่วยเหลือ ค่าอุปกรณ์การผ่าตัดฝังรากฟันเทียมด้วยคอมพิวเตอร์ช่วยเหลือ ค่าถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีมหลังการรักษา ท่านจะได้รับการสนับสนุนโดยไม่เสียค่าใช้จ่าย

อาสาสมัครสามารถเบิกค่ารักษาในส่วนของค่าทำฟันเทียมและค่าถ่ายภาพรังสีได้ตามสิทธิ์การรักษา โดยอัตราที่สามารถเบิกได้ สามารถตรวจสอบจากผู้วิจัยหรือประชาสัมพันธ์ ตึกสมเด็จย่า 93 คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัยได้

11. การชดเชยใดๆ และการรักษาที่จะจัดให้แก่อาสาสมัครในกรณีที่ได้รับอันตรายซึ่งเกี่ยวข้องกับการวิจัย

หากท่านได้รับอันตรายจากการทำวิจัย ท่านจะได้รับการดูแลจนหายโดยผู้วิจัยเป็นผู้รับผิดชอบค่าใช้จ่าย

ในกรณีที่รากฟันเทียมมีตำแหน่งที่ผิดปกติจนไม่สามารถทำฟันใส่ได้ เนื่องจากตำแหน่งที่ผิดปกติเกิดจากความผิดพลาดของการวางแผนจากงานวิจัย จะถือว่าท่านเป็นกลุ่มตัวอย่างของการวิจัย แต่กรณีที่รากฟันเทียมไม่ยึดติดกับกระดูก จะถือว่าท่านไม่ใช่กลุ่มตัวอย่างของการวิจัย เนื่องจากการที่รากฟันเทียมไม่ยึดติดกับกระดูกไม่ได้เกิดจากข้อผิดพลาดที่เกิดจากการวิจัย

ซึ่งทั้งกรณีที่รากฟันเทียมมีตำแหน่งที่ผิดปกติจนไม่สามารถทำฟันใส่ได้และกรณีรากฟันเทียมไม่ยึดติดกับกระดูก ท่านจะยังคงได้รับการดูแลรักษาตามมาตรฐานการรักษา โดยผู้วิจัยจะ

ดำเนินการถอนรากฟันเทียมออก และดูแลจนกว่าแผลจะหายเป็นปกติ หรือหากท่านต้องการฝังรากฟันเทียมอีกครั้ง ผู้วิจัยจะทำการผ่าตัดฝังรากฟันเทียมอีกครั้งให้แก่ท่าน โดยไม่มีค่าใช้จ่ายในส่วนการผ่าตัดฝังรากฟันเทียม ค่ารากฟันเทียม ค่ากระดูกเทียม แต่ท่านจะต้องจ่ายในส่วนอื่นๆ เอง เช่น ค่าถ่ายภาพรังสี ค่าใช้จ่ายในการทำฟันเทียม เป็นต้น ซึ่งท่านสามารถตรวจสอบอัตราค่าใช้จ่ายต่างๆ ได้จากคณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

12. การจ่ายค่าเดินทาง ค่าเสียเวลา (ถ้ามี ซึ่งต้องกำหนดไว้เป็นรายครั้ง) แก่อาสาสมัครที่เข้าร่วมในการวิจัย

    อาสาสมัครจะไม่ได้รับค่าใช้จ่ายสำหรับการเดินทาง

13. เหตุการณ์ที่อาจจะเกิดขึ้น หรือเหตุผลซึ่งผู้วิจัยจะต้องยกเลิกการเข้าร่วมในโครงการวิจัยของอาสาสมัคร

    หากท่านไม่สามารถปฏิบัติตามข้อตกลงในกระบวนการวิจัย เช่น ไม่สามารถมาตามนัดในการถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีม ส่งผลให้ไม่สามารถวัดความแม่นยำของการฝังรากฟันเทียมได้ ผู้วิจัยจำเป็นต้องขอยกเลิกการเข้าร่วมในโครงการของท่าน และท่านต้องทำการชำระค่าถ่ายภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ชนิดโคนบีมหลังการรักษาเอง ส่วนค่าใช้จ่ายในส่วนของค่าแผ่นจำลองนำทางผ่าตัด ค่าสแกนแบบจำลองฟัน ค่าโปรแกรมคอมพิวเตอร์ช่วยเหลือ ค่าอุปกรณ์การผ่าตัดฝังรากฟันเทียมด้วยคอมพิวเตอร์ช่วยเหลือ ท่านไม่ต้องทำการชำระย้อนหลัง โดยหากท่านยังมีความประสงค์จะรับการรักษาต่อ ผู้วิจัยจะดำเนินการให้ท่านได้รับการรักษาต่อไป

14. มีการเก็บชิ้นตัวอย่างที่ได้มาจากอาสาสมัครเอาไว้ใช้ในโครงการวิจัยในอนาคตหรือไม่ เก็บจำนวนเท่าไหร่

    อย่างไร และที่ไหน

    หลังจากจบโครงการจะไม่มีการเก็บตัวอย่างหรือภาพรังสีของอาสาสมัครไว้เป็นการส่วนตัว แต่ภาพรังสีของผู้ป่วยจะยังถูกเก็บอยู่ในระบบภาพรังสีออนไลน์ของโรงพยาบาลเช่นเดียวกับผู้ป่วยของโรงพยาบาลรายอื่น

15. การกำกับดูแลและควบคุมการดำเนินโครงการ

ผู้กำกับดูแลการวิจัย ผู้ตรวจสอบ คณะกรรมการพิจารณาจริยธรรม และคณะกรรมการที่เกี่ยวข้อง สามารถเข้าไปตรวจสอบการดำเนินโครงการ รวมทั้ง ตรวจสอบบันทึกข้อมูลของอาสาสมัคร เพื่อเป็นการยืนยันถึงขั้นตอนในการวิจัยทางคลินิกและข้อมูลอื่นๆ โดยไม่ล่วงละเมิดเอกสิทธิ์ในการปิดบังข้อมูลของอาสาสมัคร ตามกรอบที่กฎหมายและ

กฎระเบียบได้อนุญาตไว้ นอกจากนี้ โดยการลงนามให้ความยินยอม อาสาสมัครหรือ ผู้แทนตามกฎหมายจะมีสิทธิตรวจสอบและมีสิทธิที่จะได้รับข้อมูลด้วยเช่นกัน

16. จริยธรรมการวิจัย

การดำเนินการโครงการวิจัยนี้ ผู้วิจัยคำนึงถึงหลักจริยธรรมการวิจัย ดังนี้

1. หลักความเคารพในบุคคล (Respect for person) โดยการให้ข้อมูลจนอาสาสมัครเข้าใจเป็นอย่างดีและตัดสินใจอย่างอิสระในการให้ความยินยอมเข้าร่วมในการวิจัย รวมทั้งการเก็บรักษาความลับของอาสาสมัคร
2. หลักการให้ประโยชน์ไม่ก่อให้เกิดอันตราย (Beneficence/Non-Maleficence) ซึ่งได้ระบุในข้อ 8 และ 9 ว่าจะมีประโยชน์หรือความเสี่ยงกับอาสาสมัครหรือไม่
3. หลักความยุติธรรม (Justice) คือมีเกณฑ์คัดเข้าและคัดออกชัดเจน มีการกระจายความเสี่ยงและผลประโยชน์อย่างเท่าเทียมกัน โดยวิธีสุ่มเข้ากลุ่มศึกษา

17. ข้อมูลที่อาจนำไปสู่การเปิดเผยตัวของอาสาสมัครจะได้รับการปกปิด ยกเว้นว่าได้รับคำยินยอมไว้โดยกฎระเบียบและกฎหมายที่เกี่ยวข้องเท่านั้น จึงจะเปิดเผยข้อมูลแก่สาธารณชนได้ ในกรณีที่ผลการวิจัยได้รับการตีพิมพ์ ชื่อและที่อยู่ของอาสาสมัครจะต้องได้รับการปกปิดอยู่เสมอ และอาสาสมัครหรือผู้แทนตามกฎหมายจะได้รับแจ้งโดยทันท่วงที ในกรณีที่มีข้อมูลใหม่ซึ่งอาจใช้ประกอบการตัดสินใจของอาสาสมัครว่าจะยังคงเข้าร่วมในโครงการวิจัยต่อไปได้หรือไม่

18. หากท่านมีข้อสงสัยต้องการสอบถามเกี่ยวกับสิทธิของท่านหรือผู้วิจัยไม่ปฏิบัติตามที่เขียนไว้ในเอกสารข้อมูล

คำอธิบายสำหรับผู้เข้าร่วมในการวิจัย ท่านสามารถติดต่อหรือร้องเรียนได้ที่ ฝ่ายวิจัย คณะทันตแพทยศาสตร์

จุฬาลงกรณ์มหาวิทยาลัย ตึกสมเด็จย่า 93 ชั้น 10 หรือที่หมายเลขโทรศัพท์ 02-218-8866 ในเวลาทำการ

19. หากท่านต้องการยกเลิกการเข้าร่วมเป็นอาสาสมัครในโครงการนี้ ให้ท่านกรอกและส่งเอกสารขอยกเลิกมาที่

    ทพญ.ปาลิตา สมิตกาญจน์

    ภาควิชาศัลยศาสตร์ คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

    34 ถนนอังรีดูนังต์ เขตปทุมวัน กรุงเทพฯ 10330

เอกสารยินยอมเข้าร่วมการวิจัย (Consent Form)

การวิจัยเรื่อง การศึกษาเปรียบเทียบความแม่นยำของการฝังรากฟันเทียมซี่เดี่ยวระหว่างการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำ

ข้าพเจ้า (นาย/ นาง/ นางสาว/ เด็กชาย/ เด็กหญิง).....

อยู่บ้านเลขที่.....ถนน.....ตำบล/แขวง.....

อำเภอ/เขต.....จังหวัด.....รหัสไปรษณีย์.....

ก่อนที่จะลงนามในใบยินยอมให้ทำการวิจัยนี้

1. ข้าพเจ้าได้รับทราบรายละเอียดข้อมูลคำอธิบายสำหรับอาสาสมัครที่เข้าร่วมในการวิจัย รวมทั้งได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการทำวิจัย อันตรายหรืออาการที่อาจเกิดขึ้นจากการทำวิจัยหรือจากยาที่ใช้รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียดและมีความเข้าใจดีแล้ว

2. ผู้วิจัยรับรองว่าจะตอบคำถามต่างๆ ที่ข้าพเจ้าสงสัยด้วยความเต็มใจไม่ปิดบังซ่อนเร้นจนข้าพเจ้าพอใจ

3. ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับและจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆ ที่เกี่ยวข้องกระทำได้เฉพาะกรณีจำเป็นด้วยเหตุผลทางวิชาการเท่านั้น และผู้วิจัยรับรองว่าหากเกิดอันตรายใดๆ จากการวิจัยดังกล่าว ข้าพเจ้าจะได้รับการรักษาพยาบาลโดยไม่คิดมูลค่า

4. ข้าพเจ้ามีสิทธิที่จะบอกเลิกการเข้าร่วมในโครงการวิจัยนี้เมื่อใดก็ได้และการบอกเลิกการเข้าร่วมการวิจัยนี้จะไม่มีผลต่อการรักษาโรคที่ข้าพเจ้าจะพึงได้รับต่อไป

ข้าพเจ้าจึงสมัครใจเข้าร่วมโครงการวิจัยนี้ตามที่ระบุในเอกสารข้อมูลคำอธิบายสำหรับอาสาสมัครและได้ลง นามในใบยินยอมนี้ด้วยความเต็มใจ และได้รับสำเนาเอกสารใบยินยอมที่ข้าพเจ้าลงนามและลงวันที่ และเอกสารยกเลิกการเข้าร่วมวิจัย อย่างละ 1 ฉบับ เป็นที่เรียบร้อยแล้ว ในกรณีที่อาสาสมัครยังไม่บรรลุนิติภาวะจะต้องได้รับการยินยอมจากผู้ปกครองด้วย

ลงนาม..... (อาสาสมัคร) (.....) วันที่...../...../.....	ลงนาม..... (ผู้ปกครอง) (.....) วันที่...../...../.....

ลงนาม..... (ผู้วิจัยหลัก) (.....) วันที่...../...../.....	ลงนาม..... (พยาน) (.....) วันที่...../...../.....

ข้าพเจ้าไม่สามารถอ่านหนังสือได้ แต่ผู้วิจัยได้อ่านข้อความในใบยินยอมนี้ให้แก่ข้าพเจ้าฟังจนเข้าใจดีแล้ว ข้าพเจ้าจึงลงนาม หรือประทับลายนิ้วหัวแม่มือขวาของข้าพเจ้าในใบยินยอมนี้ด้วยความเต็มใจ

ลงนาม..... (อาสาสมัคร) (.....) วันที่...../...../.....	ลงนาม..... (ผู้ปกครอง) (.....) วันที่...../...../.....
ลงนาม..... (ผู้วิจัยหลัก) (.....) วันที่...../...../.....	ลงนาม.....(พยาน) (.....) วันที่...../...../.....

เอกสารยกเลิกการเข้าร่วมวิจัย (Withdrawal Form)

การวิจัยเรื่อง การศึกษาเปรียบเทียบความแม่นยำของการฝังรากฟันเทียมซี่เดี่ยวระหว่างการผ่าตัดฝังรากฟันเทียมโดยใช้วิธีคอมพิวเตอร์ช่วยเหลือแบบสถิตกับแบบช่วยเหลือผ่านการจดจำ

ข้าพเจ้า (นาย/ นาง/ นางสาว/ เด็กชาย/ เด็กหญิง).....

อยู่บ้านเลขที่.....ถนน.....ตำบล/แขวง.....

อำเภอ/เขต.....จังหวัด.....รหัสไปรษณีย์.....

ขอยกเลิกการเข้าร่วมโครงการวิจัยนี้ โดยมีเหตุผลในการยกเลิกการเข้าร่วมวิจัยคือ

- ❑ ย้ายภูมิลำเนา
- ❑ ไม่สะดวกในการเดินทาง
- ❑ เหตุผลอื่น

.....

ลงนาม.....ผู้ยกเลิก

(.....)

วันที่.....เดือน.....พ.ศ. .....

ลงนาม.....พยาน

(.....)

วันที่.....เดือน.....พ.ศ. .....

ลงนาม.....ผู้วิจัยหลัก

(.....)

วันที่.....เดือน.....พ.ศ. .....

APPENDIX B

Data output

Data in mental CAIS

	Tooth	Implant		Deviation								RFA		Torque
		Dia meter	Length	Angle	Shoulder (Base)				Apex (Tip)				B	M	
					3D	D	V	A	3D	D	V	A			
1	21	4.1	10	0.5	1.08	-0.61	-0.21	-0.87	1.07	-0.61	-0.13	-0.87	67	68	20
2	16	4.8	10	0.9	2.23	-0.31	0.46	-2.16	2.25	-0.22	0.6	-2.16	83	84	35
3	26	4.8	10	8.1	2.57	1.67	-0.1	-1.95	3.59	3.04	-0.42	-1.85	76	76	35
4	26	4.8	10	2.7	1.19	0.94	0.45	0.59	1.46	1.32	0.16	0.6	78	79	35
5	16	4.8	8	6.5	1.41	0.64	0.73	-1.02	1.9	1.53	0.56	-0.97	71	72	35
6	46	4.8	10	13.3	1.08	0.32	0	-1.03	2.47	0.49	2.3	-0.76	81	80	15
7	24	3.3	12	2.9	1.76	-0.11	-1.64	-0.63	2.21	0.25	-2.11	-0.62	68	64	20
8	16	4.8	8	7	1.48	-1.26	0.3	-0.71	2.35	-2.13	0.74	-0.65	75	78	35
9	25	4.1	10	5.1	1.8	0.56	0.33	-1.67	2.24	1.33	0.77	-1.63	78	79	35
10	17	4.1	8	1.6	0.39	-0.38	-0.05	-0.03	0.61	-0.6	-0.05	-0.03	71	77	35
11	26	4.8	8	8.7	1.04	0.74	0.55	-0.48	1.87	1.83	0.02	-0.38	63	70	20
12	46	4.8	8	16.9	1.63	-1.23	-0.43	-0.98	3.55	-2.67	-2.25	-0.64	73	73	35
13	46	4.8	10	8.4	1.22	0.33	-1	0.61	1.13	0.89	0.04	0.69	70	72	35
14	27	4.8	10	5.6	1.19	0.8	-0.85	-0.19	2.15	1.52	-1.51	-0.14	79	81	25
15	15	4.1	8	3.5	0.66	-0.03	-0.11	-0.65	0.87	-0.21	-0.57	-0.63	73	74	35
16	34	3.3	10	3.5	1.3	0.68	0.52	-0.98	1.42	1.04	0.03	-0.96	74	73	25
17	26	4.8	8	1.6	0.77	0.34	0.55	0.43	0.78	0.51	0.41	0.43	83	83	35
18	21	4.1	10	9.2	1.08	1.01	-0.37	-0.1	2.55	1.89	-1.72	0.03	79	79	35
19	11	4.1	10	0.8	0.91	0.55	0.23	0.69	1.01	0.7	0.23	0.69	56	65	10
20	36	4.8	12	7.3	1.61	-0.03	-0.77	-1.42	1.56	-0.43	0.71	-1.32	30	30	15
21	15	3.3	8	2.8	0.95	-0.39	-0.37	-0.78	1.18	-0.77	-0.45	-0.78	54	56	15
22	46	4.8	10	11.3	1.45	0.64	-0.67	-1.11	2.49	2.28	0.39	-0.92	71	70	35
23	11	3.3	10	5.8	2.23	-0.63	0.22	-2.13	2.44	-1.07	-0.69	-2.08	68	65	25
24	25	4.1	12	9.4	2.15	0.14	0.4	-2.11	3.07	0.36	2.35	-1.95	69	62	25
25	34	4.1	12	13.6	1.12	-0.46	-0.58	-0.84	3.57	-1.52	-3.19	-0.5	68	67	25
26	46	4.8	8	6.9	1.52	0.71	-0.85	-1.04	1.41	1.01	0.07	-0.98	71	72	35
27	12	4.1	12	11.5	4.03	-0.79	0.07	-3.95	4.53	-1.24	-2.27	-3.71	74	72	35
28	46	4.8	8	11.8	2.31	-0.86	-2.14	0.17	2.45	-2.15	-1.13	0.33	74	68	25
29	46	4.8	10	7.3	1.26	-0.3	-0.18	1.21	1.67	-0.03	1.06	1.29	73	74	35
30	46	4.1	10	13.6	1.14	-0.8	0.6	-0.55	3.33	-2.16	2.52	-0.27	70	72	35

D = Distal; V = Vestibular; A = Apical; B = Buccal; M = Mesial

Data in static CAIS

	Tooth	Implant		Deviation								RFA		Torque
		Dia meter	Length	Angle	Shoulder (Base)				Apex (Tip)				B	M	
					3D	D	V	A	3D	D	V	A			
1	23	3.3	10	0.1	0.81	0.6	-0.54	-0.05	0.82	0.6	-0.56	-0.05	60	62	25
2	24	4.1	12	4.9	1.27	0.95	0.22	-0.82	2.03	1.56	1.05	-0.77	30	30	15
3	45	4.1	10	0	0.29	0.13	0.14	0.22	0.29	0.13	0.14	0.22	69	71	35
4	25	4.1	10	2.4	0.76	0.38	0.17	0.64	0.96	0.38	0.59	0.65	81	82	35
5	47	4.8	10	2.7	0.52	0.1	0.17	0.48	0.78	0.58	0.2	0.49	61	63	20
6	36	4.1	10	3.5	0.84	0.14	-0.33	-0.76	1.2	0.14	-0.94	-0.74	60	59	30
7	15	4.1	10	1.9	0.36	0.32	0	-0.17	0.67	0.65	0	-0.16	74	72	35
8	36	4.8	10	1.6	0.58	0.05	-0.41	0.4	0.51	0.24	-0.2	0.4	74	74	10
9	21	4.1	10	1.7	0.84	-0.42	-0.21	-0.69	1.02	-0.72	-0.21	-0.69	71	71	35
10	17	4.8	8	6.7	2.67	0.08	1.65	2.09	2.57	-0.73	1.21	2.14	61	59	15
11	16	4.8	8	8.6	1.07	0.38	0.82	0.58	2.03	1.51	1.18	0.67	64	64	25
12	36	4.8	8	3.8	0.42	-0.17	0.38	0.05	0.94	-0.28	0.89	0.07	80	75	35
13	16	4.8	8	6.4	1.67	0.52	-0.2	1.57	1.87	0.02	-0.93	1.62	72	72	35
14	26	4.8	8	2	1.9	0.43	0.15	1.85	1.9	0.43	-0.13	1.85	74	70	15
15	24	4.1	10	0.5	0.28	-0.08	-0.01	0.26	0.32	-0.17	-0.01	0.26	62	60	15
16	11	3.3	12	6.4	0.98	0.33	0.61	-0.68	2.11	0.97	1.77	-0.61	53	57	25
17	13	3.3	10	1.6	1.72	-0.19	-0.25	-1.69	1.77	-0.47	-0.25	-1.69	70	68	25
18	26	4.8	12	3.5	1.05	0.67	-0.51	-0.62	1.61	1.41	-0.52	-0.6	66	70	25
19	36	4.8	10	2.9	0.41	-0.31	-0.25	0.07	0.91	-0.63	-0.65	0.08	63	59	15
20	46	4.1	8	1.9	1.58	0.23	1.03	1.18	1.71	0.06	1.23	1.18	58	58	35
21	24	4.1	10	0.3	0.9	-0.08	-0.01	0.89	0.9	-0.14	-0.01	0.89	72	78	35
22	45	3.3	10	3.9	0.98	-0.11	-0.46	0.86	1.26	0.51	-0.74	0.88	62	67	20
23	12	3.3	10	7.1	0.2	-0.03	-0.13	-0.16	1.32	0.7	-1.11	-0.08	55	55	15
24	15	4.1	10	4	0.99	0.66	0.25	-0.7	1.55	1.36	0.3	-0.67	64	64	20
25	46	4.8	10	1.8	0.87	-0.25	-0.57	0.61	1.12	-0.33	-0.87	0.62	62	67	15
26	36	4.8	10	0.7	0.27	-0.14	0.13	0.2	0.24	-0.14	0.01	0.2	70	66	15
27	26	4.8	8	3	0.61	0.15	0.51	0.29	0.99	0.15	0.93	0.3	53	44	15
28	16	4.8	8	6.4	1.63	-0.87	1.34	-0.35	2.5	-1.3	2.12	-0.3	44	53	15
29	16	4.8	8	0	1.42	0.04	0.28	-1.39	1.42	0.04	0.28	-1.39	70	71	25
30	25	3.3	12	3	0.48	0.18	0.29	-0.34	1.01	0.43	0.86	-0.32	54	50	15

D = Distal; V = Vestibular; A = Apical; B = Buccal; M = Mesial

APPENDIX C

Statistic output

Table 1 Distribution of implant on arch type (maxilla/mandible) and comparison of the distribution of arch type between static and mental CAIS using Chi-square test

Crosstab

Count

		ArchType		
		Maxilla	Mandible	Total
GROUP	Mental	19	11	30
	Static	20	10	30
Total		39	21	60

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.073[a]	1	.787		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.073	1	.787		
Fisher's Exact Test				1.000	.500
Linear-by-Linear Association	.072	1	.788		
N of Valid Cases	60				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.50.

b. Computed only for a 2x2 table

Table 2 Distribution of implant on side on arch (right/left) and comparison of the distribution of side on arch between static and mental CAIS using Chi-square test

Crosstab

Count

		Side		
		Right	Left	Total
GROUP	Mental	17	13	30
	Static	15	15	30
Total		32	28	60

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.268[a]	1	.605		
Continuity Correction[b]	.067	1	.796		
Likelihood Ratio	.268	1	.605		
Fisher's Exact Test				.796	.398
Linear-by-Linear Association	.263	1	.608		
N of Valid Cases	60				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.00.

b. Computed only for a 2x2 table

Table 3 Distribution of location of implant (anterior/premolar/molar) and comparison of the distribution of location of the implant between static and mental CAIS using Chi-square test

Crosstab

Count

		Location			Total
		Anterior tooth	Premolar	Molar	
GROUP	Mental	5	7	18	30
	Static	5	9	16	30
Total		10	16	34	60

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.368[a]	2	.832
Likelihood Ratio	.368	2	.832
Linear-by-Linear Association	.114	1	.735
N of Valid Cases	60		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.00.

Table 4 Distribution of diameter of implant (3.3/4.1/4.8 mm) and comparison of the distribution of diameter of the implant between static and mental CAIS using Chi-square test

Crosstab

Count

		Diameter			Total
		3.3	4.1	4.8	
GROUP	Mental	4	10	16	30
	Static	6	10	14	30
Total		10	20	30	60

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.533[a]	2	.766
Likelihood Ratio	.536	2	.765
Linear-by-Linear Association	.472	1	.492
N of Valid Cases	60		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.00.

Table 5 Distribution of length of implant (8/10/12 mm) and comparison of the distribution of length of the implant between static and mental CAIS using Chi-square test

Crosstab

Count

		Length			Total
		8	10	12	
GROUP	Mental	10	15	5	30
	Static	9	17	4	30
Total		19	32	9	60

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.289[a]	2	.866
Likelihood Ratio	.289	2	.865
Linear-by-Linear Association	.000	1	1.000
N of Valid Cases	60		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 4.50.

Angle deviation

Table 6 Descriptive analysis of the angle deviation in static and mental CAIS

Descriptives

	GROUP			Statistic	Std. Error
Angle	Mental	Mean		6.9367	.80533
		95% Confidence Interval for Mean	Lower Bound	5.2896	
			Upper Bound	8.5838	
		5% Trimmed Mean		6.7963	
		Median		6.9500	
		Variance		19.457	
		Std. Deviation		4.41100	
		Minimum		.50	
		Maximum		16.90	
		Range		16.40	
		Interquartile Range		7.00	
		Skewness		.363	.427
		Kurtosis		-.633	.833
	Static	Mean		3.1100	.42738
		95% Confidence Interval for Mean	Lower Bound	2.2359	
			Upper Bound	3.9841	
		5% Trimmed Mean		3.0056	
		Median		2.8000	
		Variance		5.480	
		Std. Deviation		2.34084	
		Minimum		.00	
		Maximum		8.60	
		Range		8.60	
		Interquartile Range		2.62	
		Skewness		.665	.427
		Kurtosis		-.334	.833

Table 7 Normality test of the angle deviation in static and mental CAIS using Kolmogorov-Smirnov test

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	GROUP	Statistic	df	Sig.	Statistic	df	Sig.
Angle	Mental	.115	30	.200*	.960	30	.302
	Static	.120	30	.200*	.931	30	.052

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Test of normality used Kolmogorov-Smirnov test at confidence interval of 95%. The significant was 0.2, mean non-normal distribution. Thus, angle deviation were compared between static and mental CAIS by Mann Whitney U test.

Table 8 Comparison of the angle deviation between static and mental CAIS using Mann Whitney U test

Test Statistics[a]

	Angle
Mann-Whitney U	215.500
Wilcoxon W	680.500
Z	-3.468
Asymp. Sig. (2-tailed)	.001

a. Grouping Variable: GROUP

Table 9 Effect of sex, arch type, side on arch, location, diameter and length of implant to the angle deviation in static CAIS using Multiple linear regression

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.727	3.212		2.095	.047
	Location	.745	1.209	.243	.616	.544
	ArchType	-1.175	1.020	-.241	-1.152	.261
	Side	-1.479	.909	-.321	-1.627	.117
	Diameter	-.645	1.162	-.216	-.555	.584
	Length	-.072	.854	-.020	-.085	.933

a. Dependent Variable: Angle

b. Selecting only cases for which GROUP = Static

Table 10 Effect of sex, arch type, side on arch, location, diameter and length of implant to the angle deviation in mental CAIS using Multiple linear regression

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.100	4.525		.464	.647
	Location	-.062	1.678	-.011	-.037	.971
	ArchType	1.674	1.816	.186	.922	.366
	Side	-1.782	1.678	-.204	-1.062	.299
	Diameter	1.376	1.709	.226	.805	.429
	Length	1.065	1.276	.169	.834	.412

a. Dependent Variable: Angle

b. Selecting only cases for which GROUP = Mental

The arch type, side on arch, location, diameter and length of implant were not possible effect to the angle deviation both in static and mental CAIS at 95% confident interval.

Deviation at implant shoulder

Table 11 Descriptive analysis of the deviation at implant shoulder in static and mental CAIS

Descriptives

	GROUP			Statistic	Std. Error
Shoulder3D	Mental	Mean		1.4853	.12859
		95% Confidence Interval for Mean	Lower Bound	1.2223	
			Upper Bound	1.7483	
		5% Trimmed Mean		1.4269	
		Median		1.2800	
		Variance		.496	
		Std. Deviation		.70432	
		Minimum		.39	
		Maximum		4.03	
		Range		3.64	
		Interquartile Range		.69	
		Skewness		1.738	.427
		Kurtosis		4.788	.833
	Static	Mean		.9457	.10591
		95% Confidence Interval for Mean	Lower Bound	.7291	
			Upper Bound	1.1623	
		5% Trimmed Mean		.9043	
		Median		.8550	
		Variance		.337	
		Std. Deviation		.58011	
		Minimum		.20	
		Maximum		2.67	
		Range		2.47	
		Interquartile Range		.84	
		Skewness		1.038	.427
		Kurtosis		1.171	.833

Descriptives

	GROUP			Statistic	Std. Error
ShoulderDistal	Mental	Mean		.6087	.06861
		95% Confidence Interval for Mean	Lower Bound	.4683	
			Upper Bound	.7490	
		5% Trimmed Mean		.5894	
		Median		.6200	
		Variance		.141	
		Std. Deviation		.37580	
		Minimum		.03	
		Maximum		1.67	
		Range		1.64	
		Interquartile Range		.47	
		Skewness		.759	.427
		Kurtosis		.957	.833
	Static	Mean		.2997	.04518
		95% Confidence Interval for Mean	Lower Bound	.2073	
			Upper Bound	.3921	
		5% Trimmed Mean		.2798	
		Median		.2100	
		Variance		.061	
		Std. Deviation		.24743	
		Minimum		.03	
		Maximum		.95	
		Range		.92	
		Interquartile Range		.32	
		Skewness		1.170	.427
		Kurtosis		.718	.833

Descriptives

	GROUP			Statistic	Std. Error
ShouldrVestibular	Mental	Mean		.5243	.08340
		95% Confidence Interval for Mean	Lower Bound	.3538	
			Upper Bound	.6949	
		5% Trimmed Mean		.4720	
		Median		.4400	
		Variance		.209	
		Std. Deviation		.45682	
		Minimum		.00	
		Maximum		2.14	
		Range		2.14	
		Interquartile Range		.47	
		Skewness		2.001	.427
		Kurtosis		5.155	.833
	Static	Mean		.4007	.06943
		95% Confidence Interval for Mean	Lower Bound	.2587	
			Upper Bound	.5427	
		5% Trimmed Mean		.3591	
		Median		.2650	
		Variance		.145	
		Std. Deviation		.38027	
		Minimum		.00	
		Maximum		1.65	
		Range		1.65	
		Interquartile Range		.35	
		Skewness		1.885	.427
		Kurtosis		3.781	.833

Descriptives

	GROUP			Statistic	Std. Error
ShoulderApical	Mental	Mean		1.0360	.14720
		95% Confidence Interval for Mean	Lower Bound	.7349	
			Upper Bound	1.3371	
		5% Trimmed Mean		.9619	
		Median		.8550	
		Variance		.650	
		Std. Deviation		.80623	
		Minimum		.03	
		Maximum		3.95	
		Range		3.92	
		Interquartile Range		.68	
		Skewness		1.819	.427
		Kurtosis		4.760	.833
	Static	Mean		.6887	.10088
		95% Confidence Interval for Mean	Lower Bound	.4823	
			Upper Bound	.8950	
		5% Trimmed Mean		.6507	
		Median		.6150	
		Variance		.305	
		Std. Deviation		.55255	
		Minimum		.05	
		Maximum		2.09	
		Range		2.04	
		Interquartile Range		.62	
		Skewness		1.087	.427
		Kurtosis		.494	.833

Table 12 Normality test of the deviation at implant shoulder between static and mental CAIS using Kolmogorov-Smirnov test

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	GROUP	Statistic	df	Sig.	Statistic	df	Sig.
Shoulder3D	Mental	.152	30	.075	.866	30	.001
	Static	.148	30	.090	.919	30	.026
ShoulderDistal	Mental	.105	30	.200*	.955	30	.226
	Static	.171	30	.025	.874	30	.002
ShouldrVestibular	Mental	.168	30	.031	.819	30	.000
	Static	.181	30	.013	.804	30	.000
ShoulderApical	Mental	.198	30	.004	.844	30	.000
	Static	.158	30	.053	.888	30	.004

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 13 Comparison of the deviation at implant shoulder between static and mental CAIS using Mann Whitney U test

Test Statistics[a]

	Shoulder3D	ShoulderDistal	ShouldrVestibular	ShoulderApical
Mann-Whitney U	220.500	223.000	355.500	313.000
Wilcoxon W	685.500	688.000	820.500	778.000
Z	-3.393	-3.357	-1.397	-2.026
Asymp. Sig. (2-tailed)	.001	.001	.162	.043

a. Grouping Variable: GROUP

Statistical different was found at 3D (*P = 0.001*), mesio-distal (*P = 0.001*) and apico-coronal (*P = 0.043*) deviation at implant shoulder, while at bucco-lingual deviation was not found the statistical different at 95% confident interval.

Table 14 Effect of arch type, side on arch, location, diameter and length of implant to the deviation at implant shoulder in static CAIS using Multiple linear regression

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.074	.752		2.758	.011
	Location	.173	.283	.228	.610	.547
	ArchType	-.302	.239	-.250	-1.266	.218
	Side	-.174	.213	-.152	-.817	.422
	Diameter	-.147	.272	-.199	-.540	.594
	Length	-.295	.200	-.329	-1.473	.154

a. Dependent Variable: Shoulder3D

b. Selecting only cases for which GROUP = Static

Table 15 Effect of arch type, side on arch, location, diameter and length of implant to the deviation at implant shoulder in mental CAIS using Multiple linear regression

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.503	.717		2.095	.047
	Location	-.271	.266	-.298	-1.018	.319
	ArchType	-.056	.288	-.039	-.193	.848
	Side	-.219	.266	-.157	-.824	.418
	Diameter	.170	.271	.174	.626	.537
	Length	.341	.202	.338	1.685	.105

a. Dependent Variable: Shoulder3D

b. Selecting only cases for which GROUP = Mental

The arch type, side on arch, location, diameter and length of implant were not possible effect to the deviation at implant shoulder both in static and mental CAIS at 95% confident interval.

Deviation at implant apex

Table 16 Descriptive analysis of the deviation at implant apex in static and mental CAIS

Descriptives

	GROUP			Statistic	Std. Error
Apex3D	Mental	Mean		2.1060	.17655
		95% Confidence Interval for Mean	Lower Bound	1.7449	
			Upper Bound	2.4671	
		5% Trimmed Mean		2.0687	
		Median		2.1800	
		Variance		.935	
		Std. Deviation		.96703	
		Minimum		.61	
		Maximum		4.53	
		Range		3.92	
		Interquartile Range		1.15	
		Skewness		.562	.427
		Kurtosis		-.089	.833
	Static	Mean		1.2777	.11494
		95% Confidence Interval for Mean	Lower Bound	1.0426	
			Upper Bound	1.5127	
		5% Trimmed Mean		1.2639	
		Median		1.1600	
		Variance		.396	
		Std. Deviation		.62953	
		Minimum		.24	
		Maximum		2.57	
		Range		2.33	
		Interquartile Range		.91	
		Skewness		.300	.427
		Kurtosis		-.597	.833

Descriptives

	GROUP			Statistic	Std. Error
ApexDistal	Mental	Mean		1.1933	.14554
		95% Confidence Interval for Mean	Lower Bound	.8957	
			Upper Bound	1.4910	
		5% Trimmed Mean		1.1589	
		Median		1.0550	
		Variance		.635	
		Std. Deviation		.79716	
		Minimum		.03	
		Maximum		3.04	
		Range		3.01	
		Interquartile Range		1.34	
		Skewness		.546	.427
		Kurtosis		-.524	.833
	Static	Mean		.5593	.08460
		95% Confidence Interval for Mean	Lower Bound	.3863	
			Upper Bound	.7324	
		5% Trimmed Mean		.5343	
		Median		.4500	
		Variance		.215	
		Std. Deviation		.46337	
		Minimum		.02	
		Maximum		1.56	
		Range		1.54	
		Interquartile Range		.58	
		Skewness		.948	.427
		Kurtosis		-.113	.833

Descriptives

	GROUP			Statistic	Std. Error
ApexVestibular	Mental	Mean		.9817	.16836
		95% Confidence Interval for Mean	Lower Bound	.6373	
			Upper Bound	1.3260	
		5% Trimmed Mean		.9246	
		Median		.6450	
		Variance		.850	
		Std. Deviation		.92213	
		Minimum		.02	
		Maximum		3.19	
		Range		3.17	
		Interquartile Range		1.61	
		Skewness		.881	.427
		Kurtosis		-.465	.833
	Static	Mean		.6630	.09791
		95% Confidence Interval for Mean	Lower Bound	.4628	
			Upper Bound	.8632	
		5% Trimmed Mean		.6252	
		Median		.6200	
		Variance		.288	
		Std. Deviation		.53628	
		Minimum		.00	
		Maximum		2.12	
		Range		2.12	
		Interquartile Range		.77	
		Skewness		.785	.427
		Kurtosis		.485	.833

Descriptives

	GROUP			Statistic	Std. Error
ApexApical	Mental	Mean		.9620	.14224
		95% Confidence Interval for Mean	Lower Bound	.6711	
			Upper Bound	1.2529	
		5% Trimmed Mean		.8898	
		Median		.7250	
		Variance		.607	
		Std. Deviation		.77907	
		Minimum		.03	
		Maximum		3.71	
		Range		3.68	
		Interquartile Range		.82	
		Skewness		1.755	.427
		Kurtosis		4.161	.833
	Static	Mean		.6863	.10272
		95% Confidence Interval for Mean	Lower Bound	.4762	
			Upper Bound	.8964	
		5% Trimmed Mean		.6459	
		Median		.6150	
		Variance		.317	
		Std. Deviation		.56262	
		Minimum		.05	
		Maximum		2.14	
		Range		2.09	
		Interquartile Range		.63	
		Skewness		1.117	.427
		Kurtosis		.576	.833

Table 17 Normality test of the deviation at implant apex between static and mental CAIS using Kolmogorov-Smirnov test

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	GROUP	Statistic	df	Sig.	Statistic	df	Sig.
Apex3D	Mental	.123	30	.200*	.957	30	.261
	Static	.126	30	.200*	.967	30	.470
ApexDistal	Mental	.102	30	.200*	.952	30	.190
	Static	.156	30	.059	.877	30	.002
ApexVestibular	Mental	.224	30	.001	.863	30	.001
	Static	.151	30	.080	.922	30	.030
ApexApical	Mental	.224	30	.001	.846	30	.001
	Static	.174	30	.021	.881	30	.003

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 18 Comparison of the deviation at implant apex between static and mental CAIS using Mann Whitney U test

Test Statistics[a]

	Apex3D	ApexDistal	ApexVestibular	ApexApical
Mann-Whitney U	221.500	226.500	390.500	340.000
Wilcoxon W	686.500	691.500	855.500	805.000
Z	-3.379	-3.305	-.880	-1.627
Asymp. Sig. (2-tailed)	.001	.001	.379	.104

a. Grouping Variable: GROUP

Statistical different was found at 3D *(P = 0.001)* and mesio-distal (*P = 0.001*) deviation at implant apex, while at bucco-lingual and apico-coronal deviation was not found the statistical different at 95% confident interval.

Table 14 Effect of arch type, side on arch, location, diameter and length of implant to the deviation at implant apex in static CAIS using Multiple linear regression

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.696	.828		3.256	.003
	Location	.203	.312	.247	.651	.521
	ArchType	-.404	.263	-.308	-1.538	.137
	Side	-.398	.234	-.322	-1.701	.102
	Diameter	-.220	.300	-.275	-.735	.470
	Length	-.143	.220	-.147	-.651	.521

a. Dependent Variable: Apex3D

b. Selecting only cases for which GROUP = Static

Table 15 Effect of arch type, side on arch, location, diameter and length of implant to the deviation at implant apex in mental CAIS using Multiple linear regression

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.634	1.016		1.609	.121
	Location	-.106	.377	-.085	-.281	.781
	ArchType	-.161	.408	-.082	-.395	.696
	Side	-.127	.377	-.066	-.337	.739
	Diameter	.093	.383	.070	.243	.810
	Length	.495	.286	.358	1.728	.097

a. Dependent Variable: Apex3D

b. Selecting only cases for which GROUP = Mental

The arch type, side on arch, location, diameter and length of implant were not possible effect to the deviation at implant apex both in static and mental CAIS at 95% confident interval.

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